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(52) UK CL (Edition Q)
E1F FFD FGA

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US 5172779 A

(58) Field of Search
UK CL (Edition P) E1F FFD FGA FGC
INT CL^{6} E21B

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(54) Abstract Title
Cutter element with elongate crest

(57) A drill bit has at least one roller cone with at least one cutter element having a base portion. The base portion is adapted to fit in a socket on the cone. From the base portion projects an extending portion which is the cutter head of the cutter element. The cutter head has an elongate crest. The crest is non-rectilinear and can be arcuate, S-shaped, or J-shaped. Also disclosed is a method of manufacture of the cutter elements and cutter elements with non-positive draft, i.e. where the cutter head does not taper within an envelope described by the base portion.

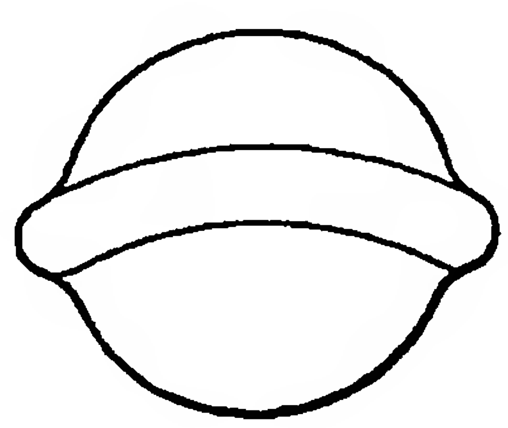


Fig. 13A

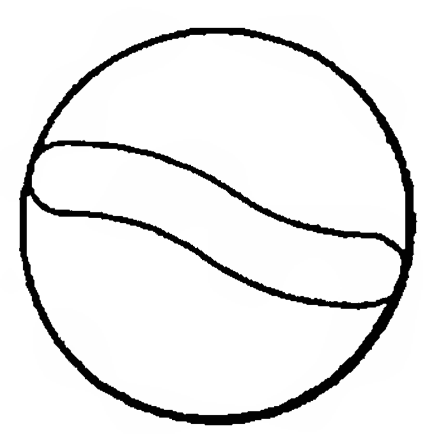


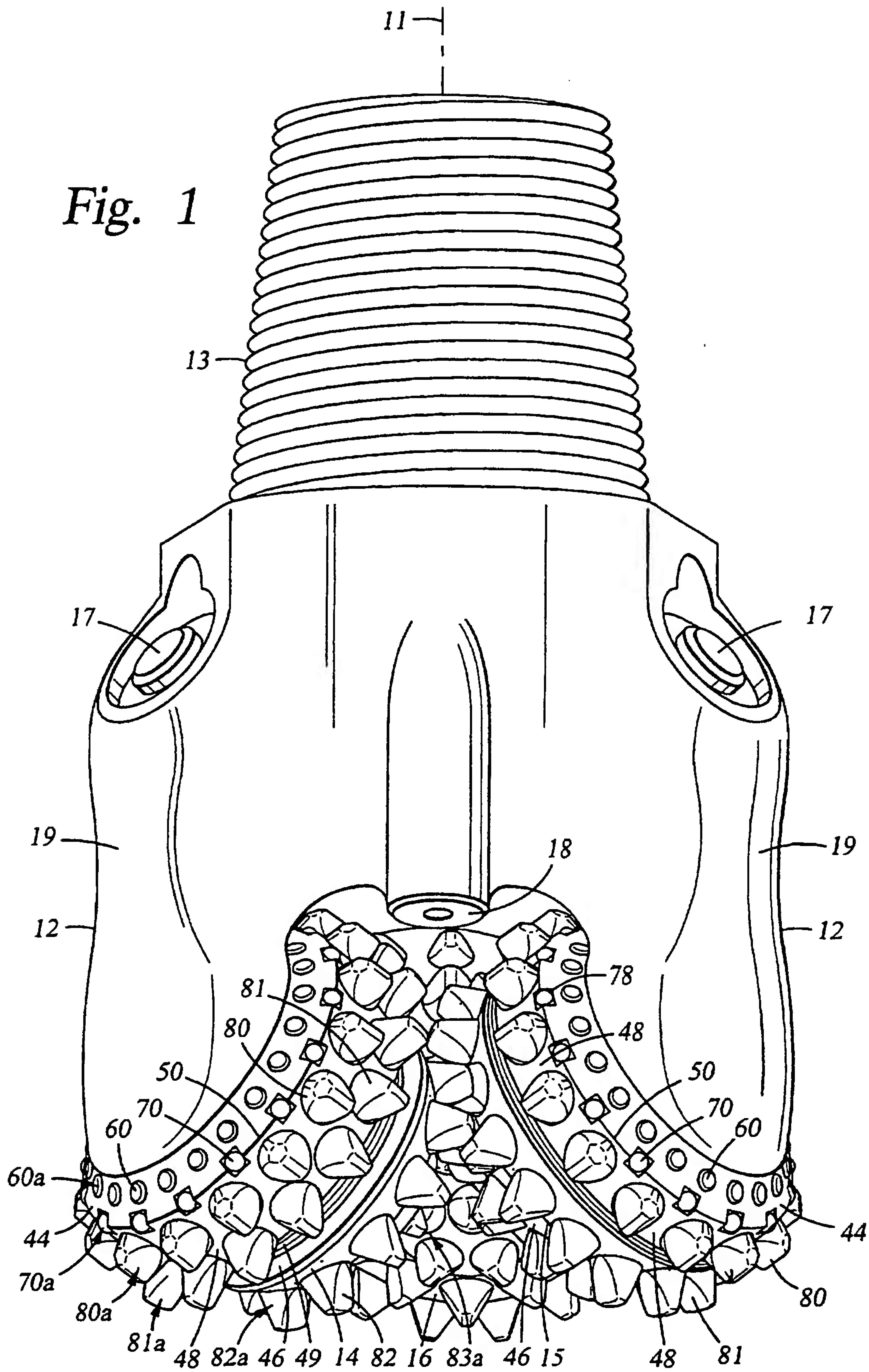
Fig. 14A

The reference to figures 8D and 15A - 15C of the drawings in the printed specification are to be treated as omitted under Section 15(2) or (3) of the Patents Act 1977.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 328 966 A

Fig. 1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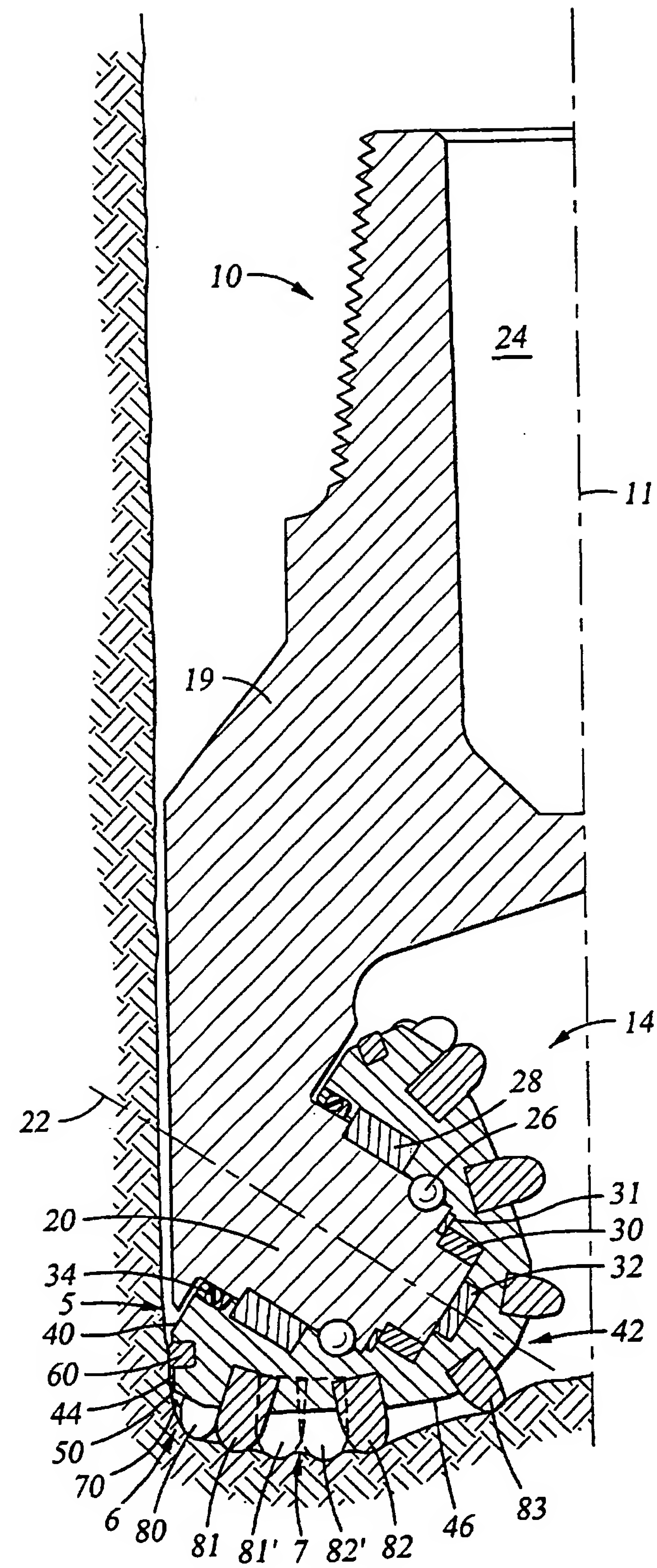
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Fig. 2

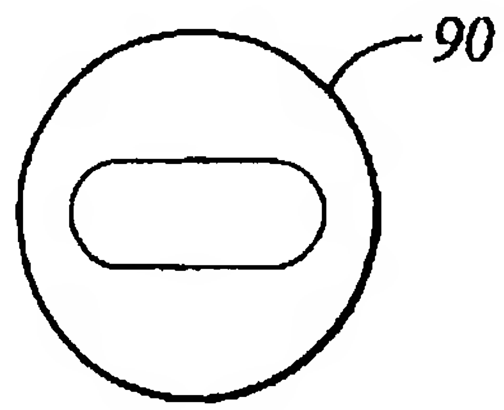

Fig. 3A
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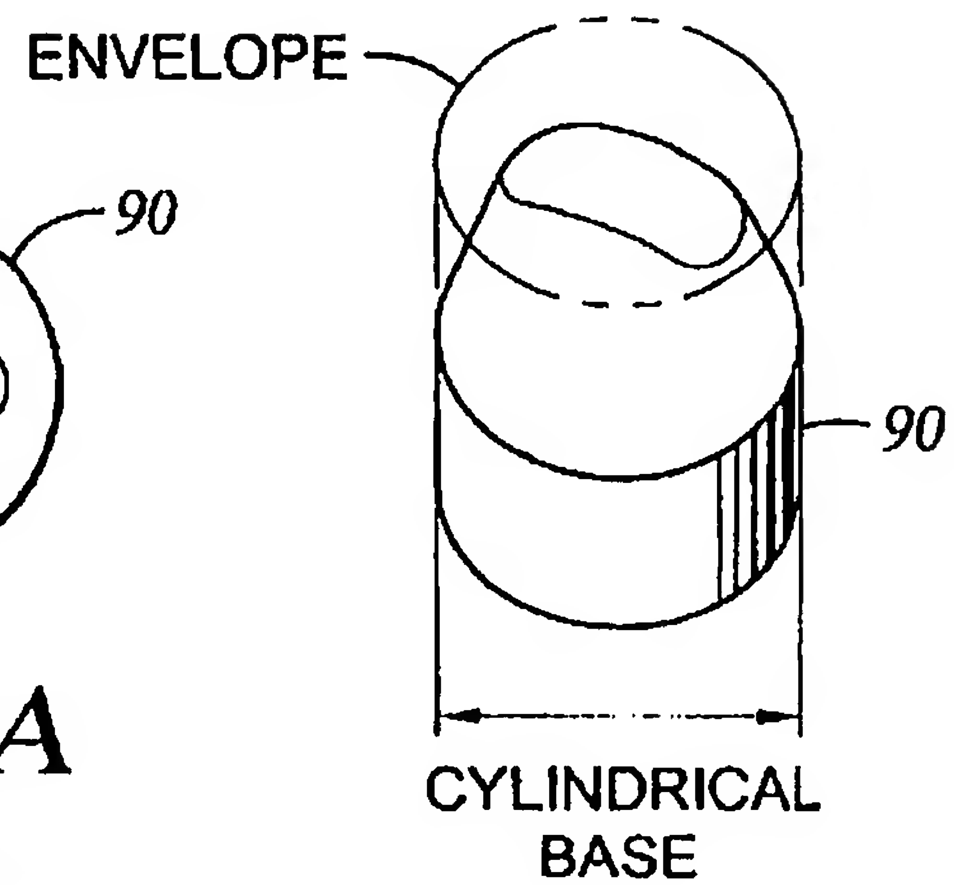


Fig. 3D
(PRIOR ART)

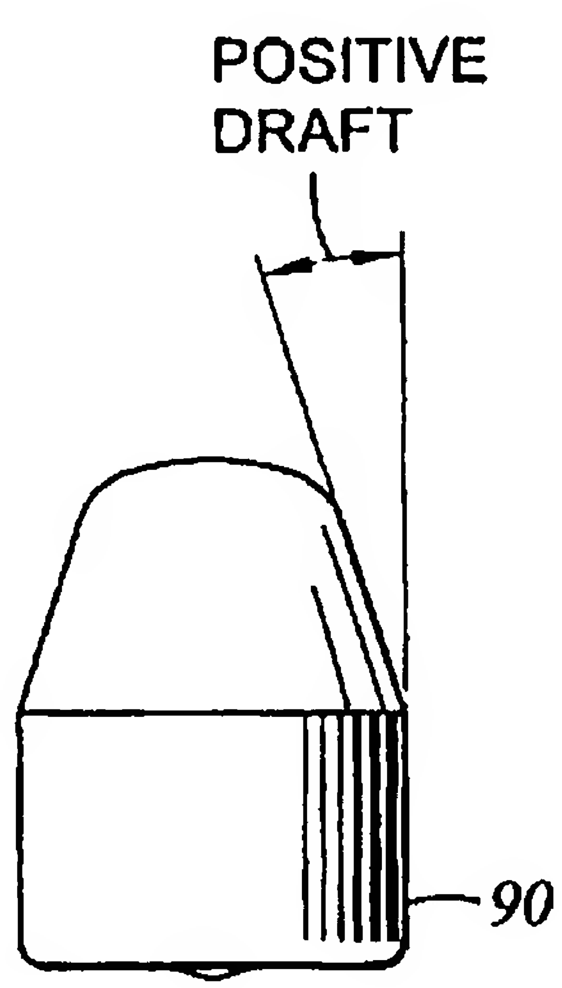


Fig. 3B
(PRIOR ART)

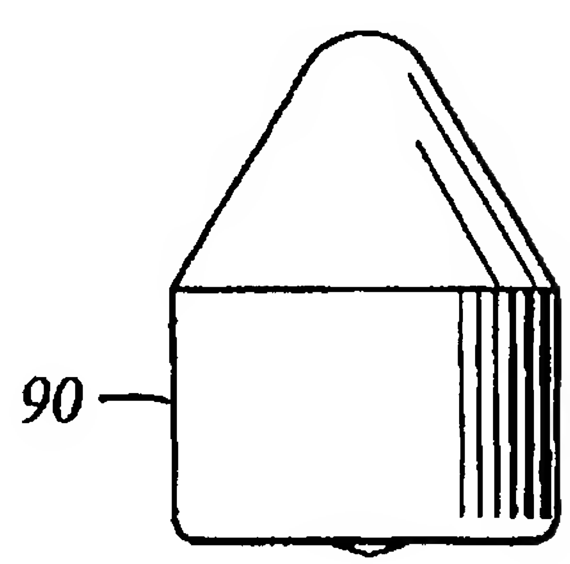


Fig. 3C
(PRIOR ART)

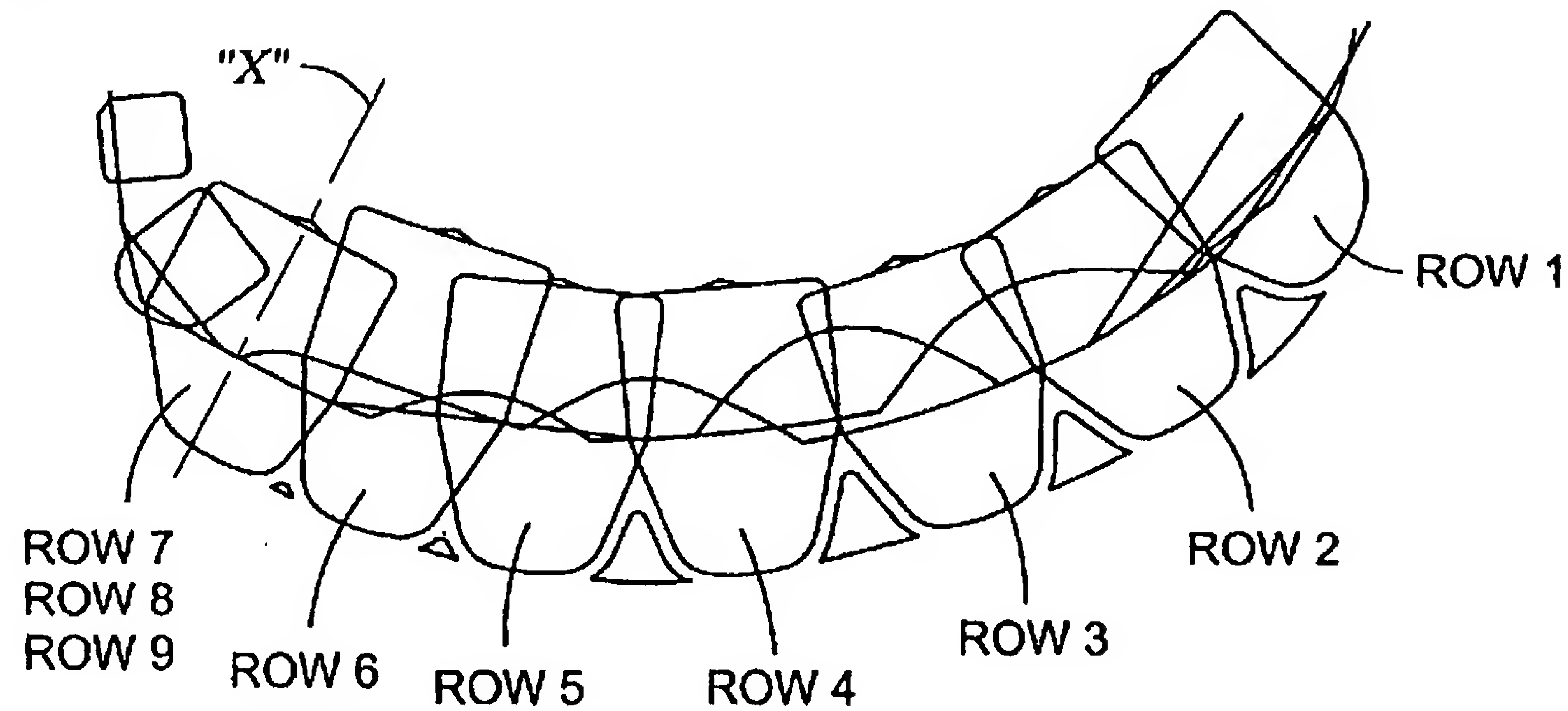
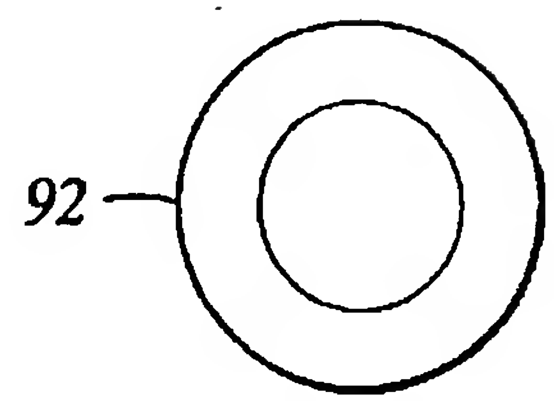


Fig. 3E
(PRIOR ART)



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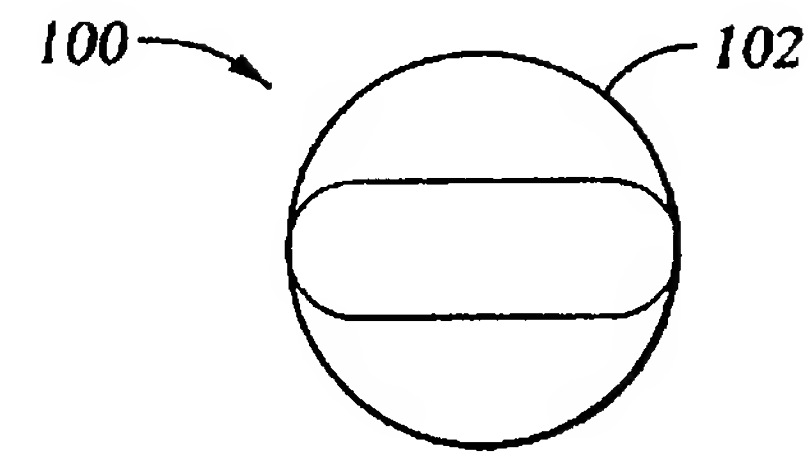

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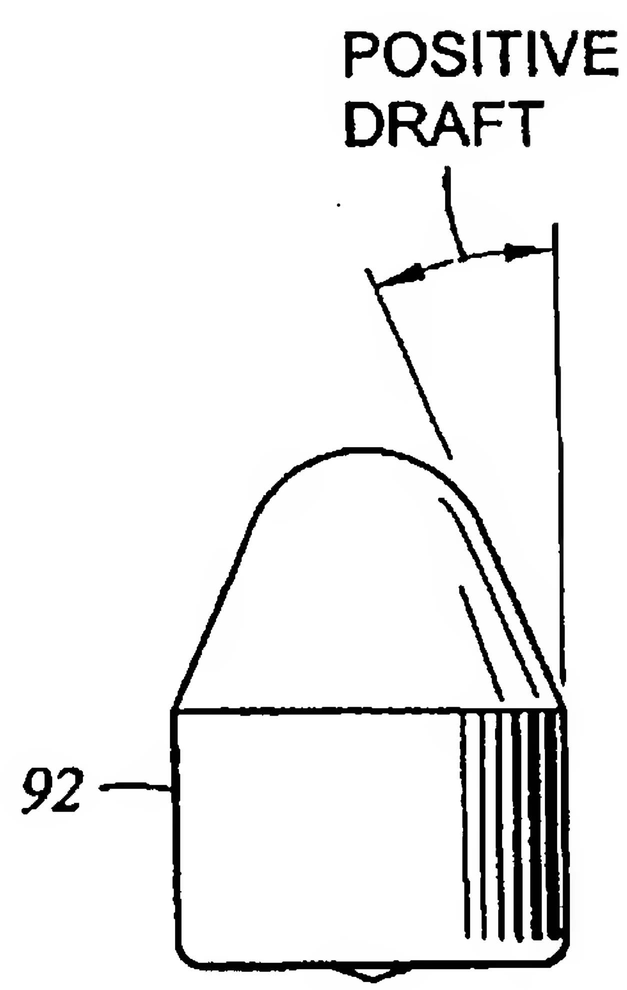

Fig. 4B
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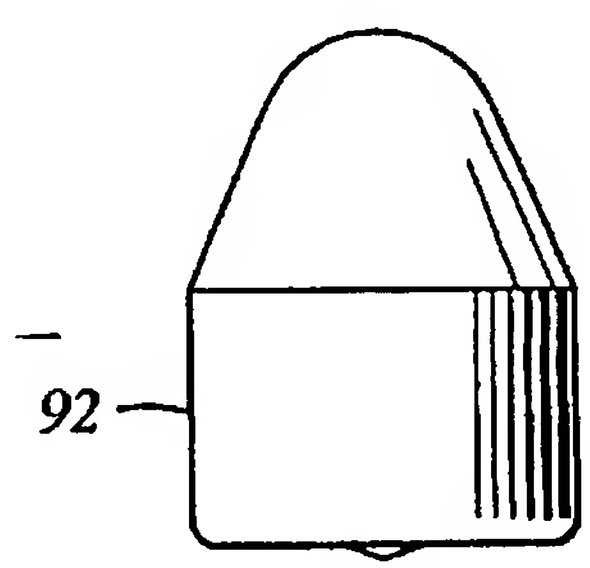

Fig. 4C
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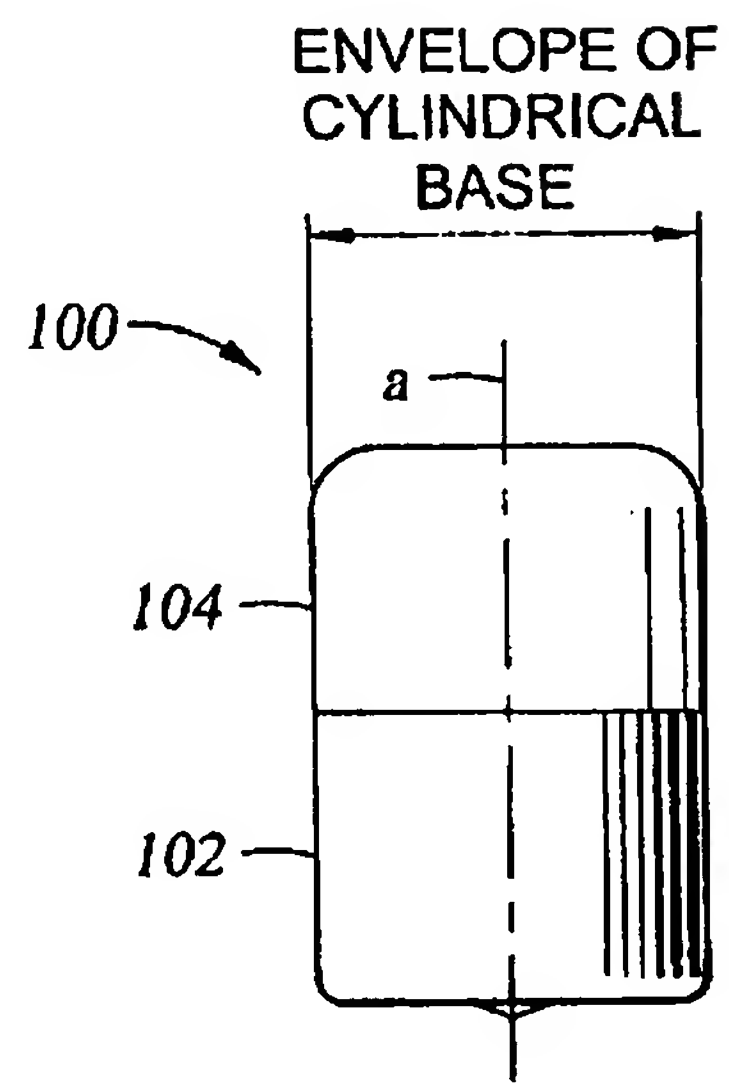

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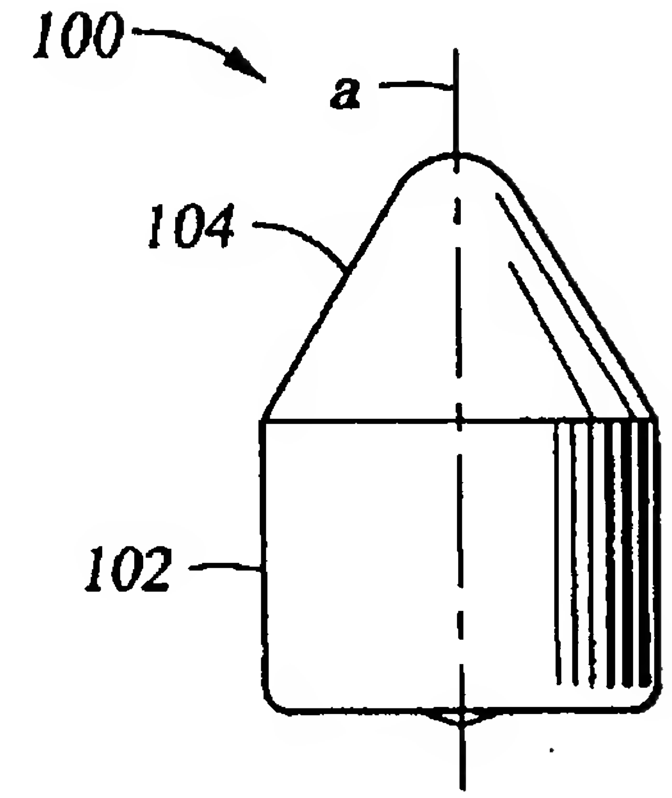
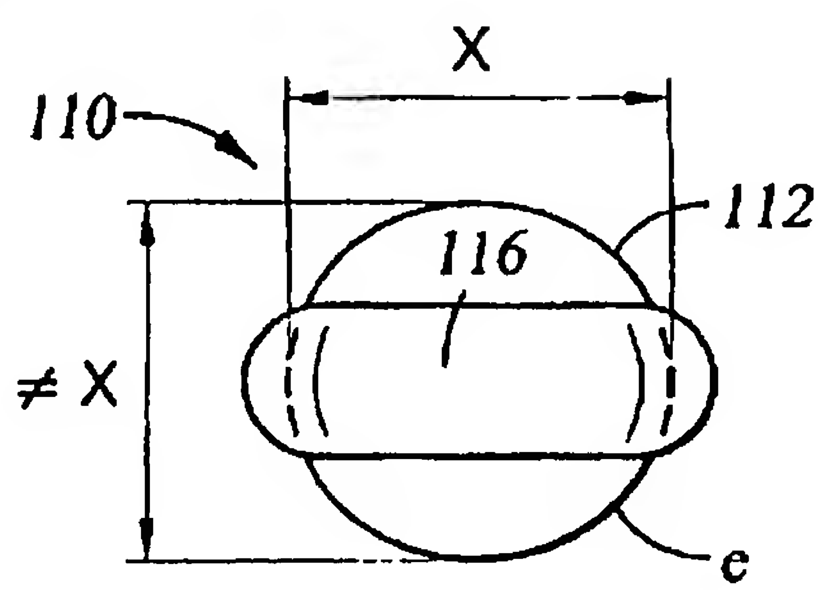


Fig. 5C



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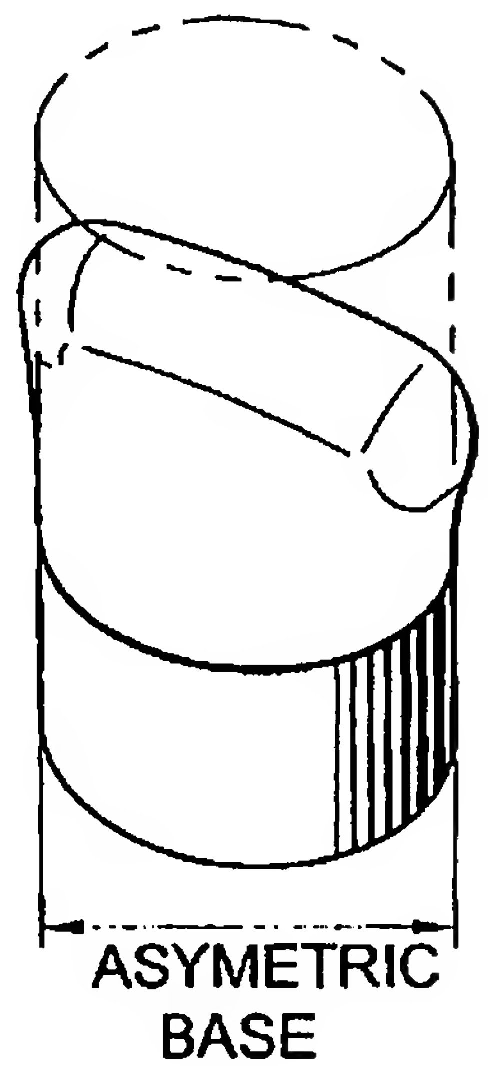

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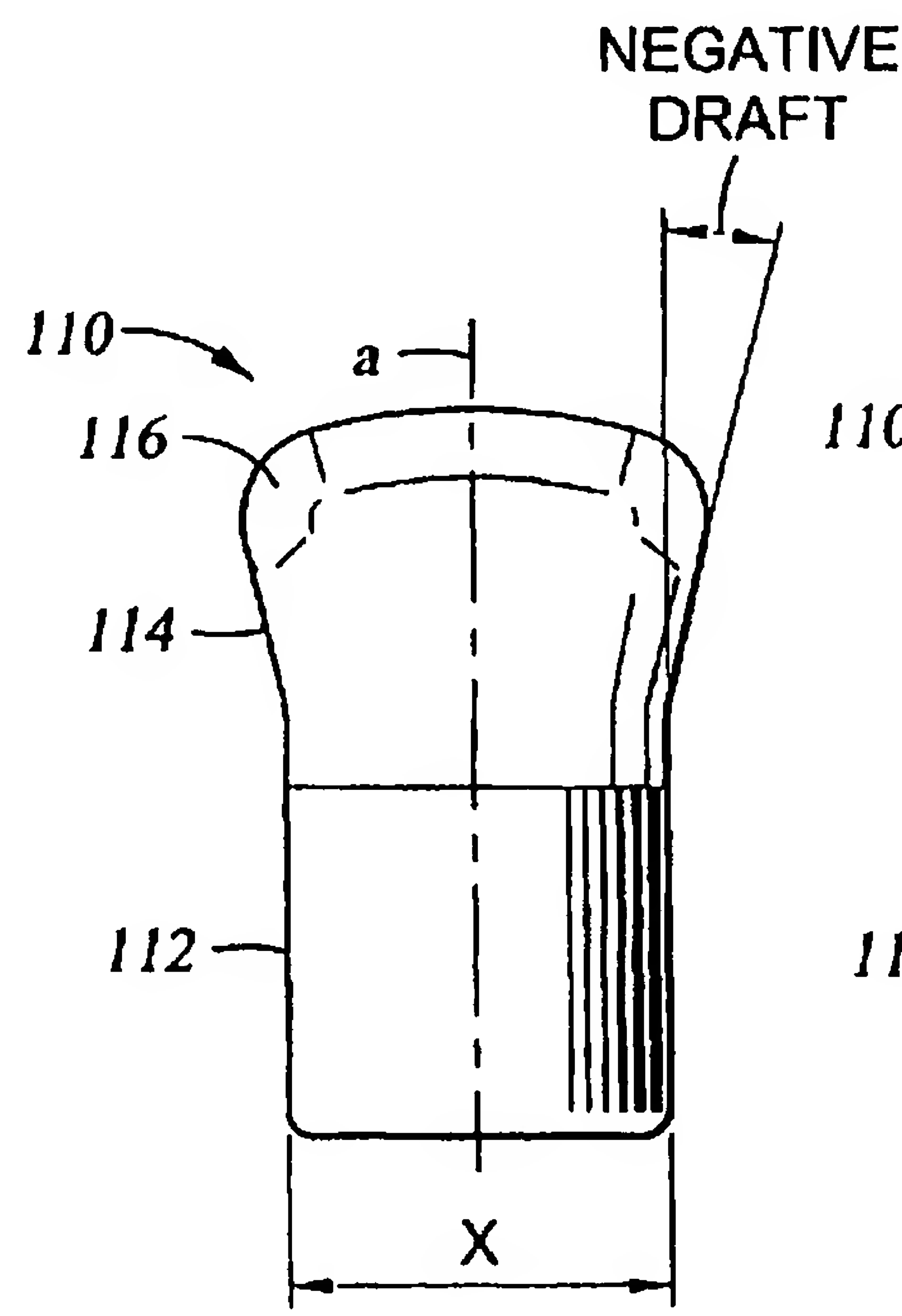

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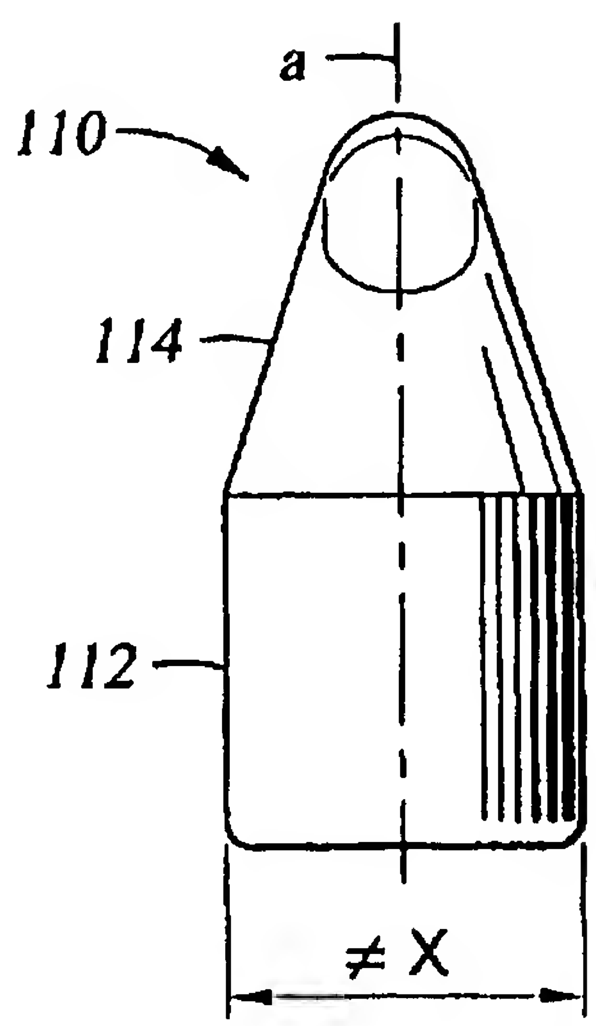

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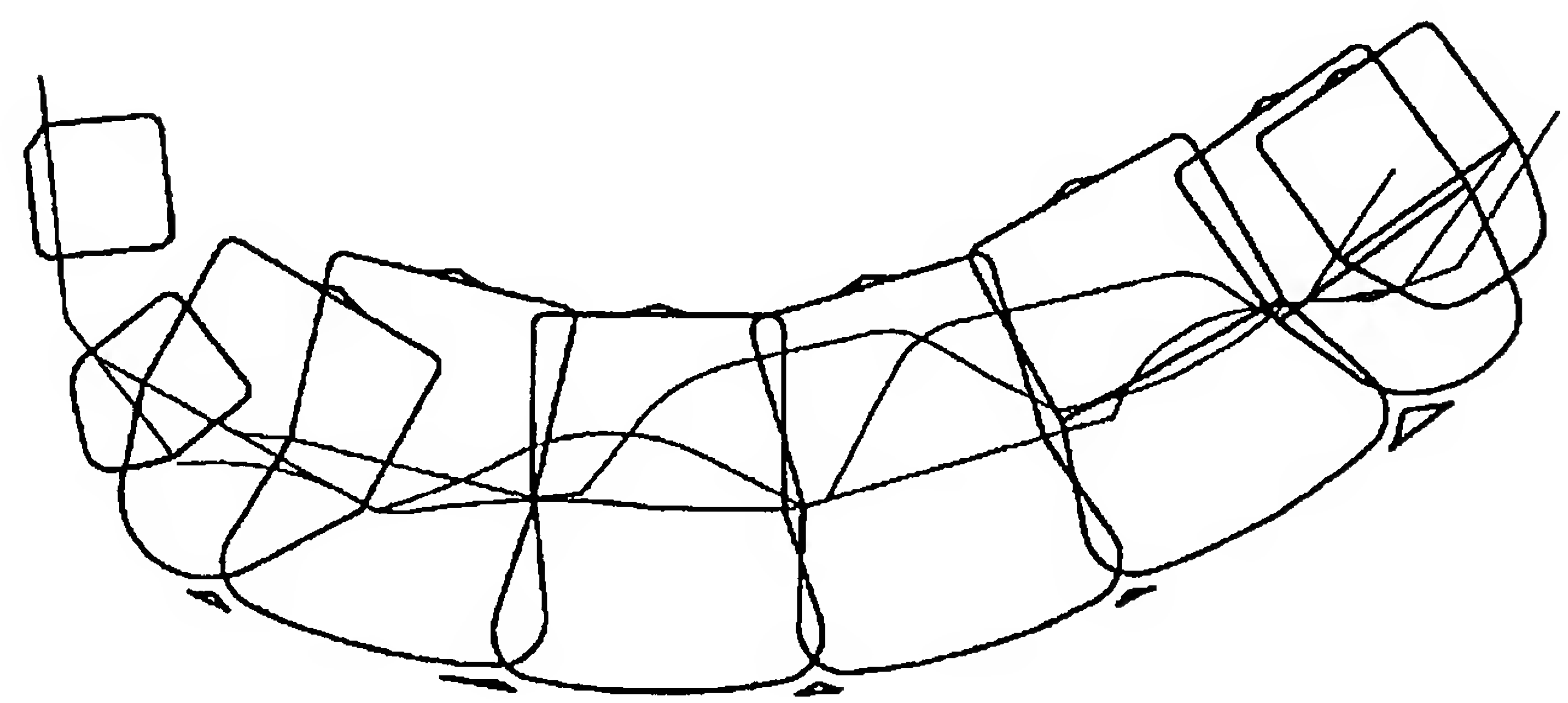
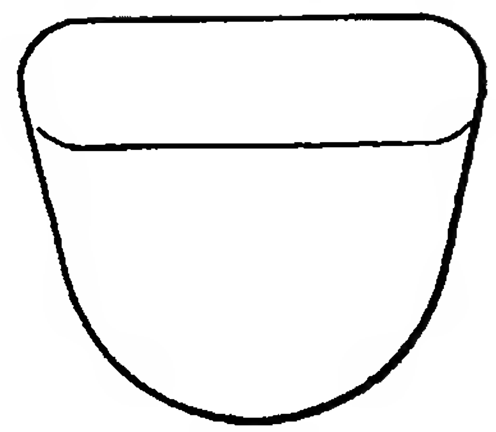


Fig. 6E



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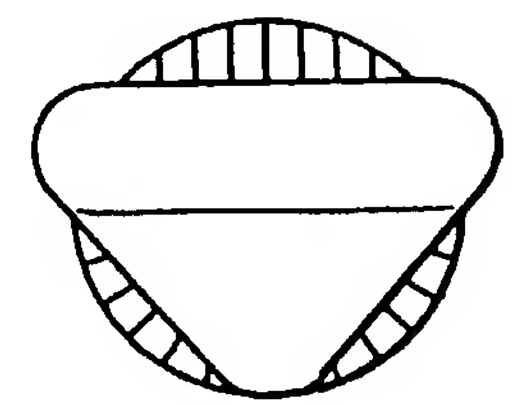

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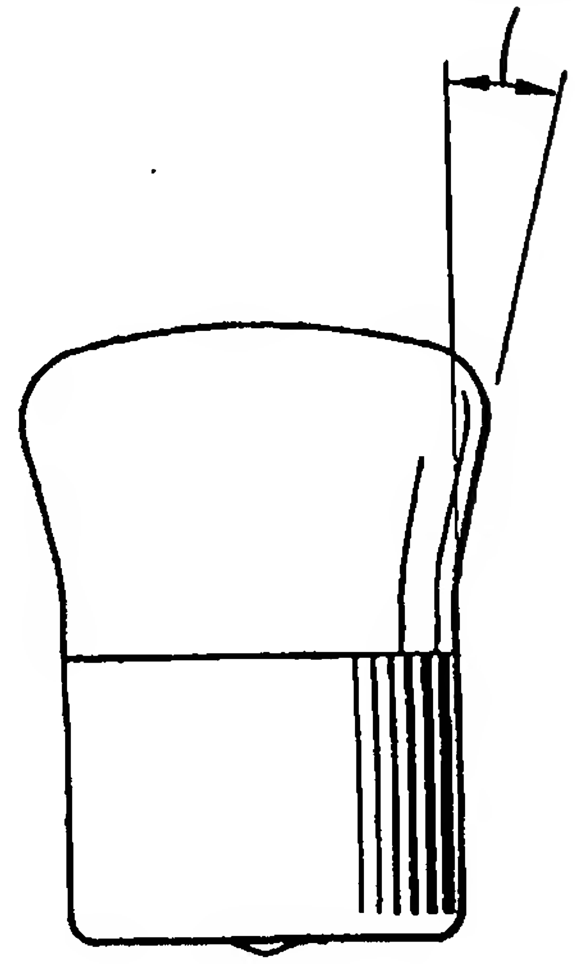

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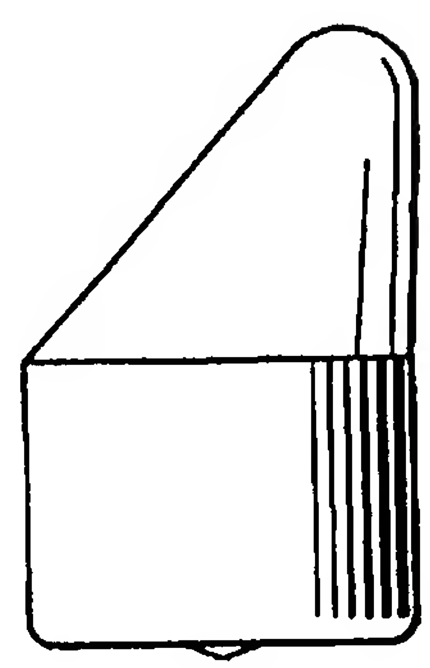

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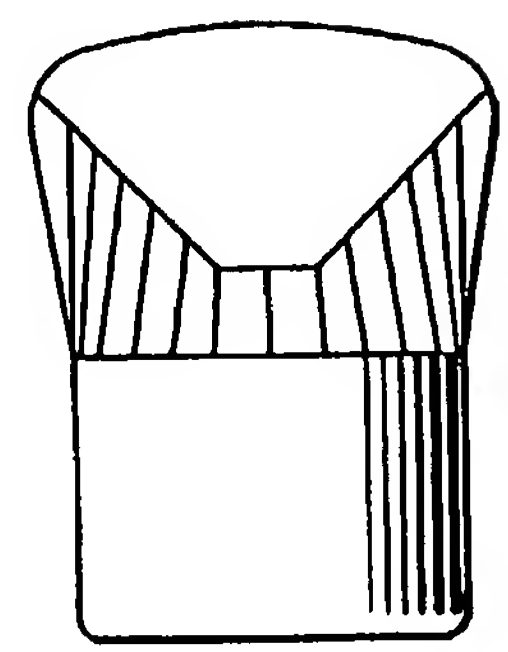

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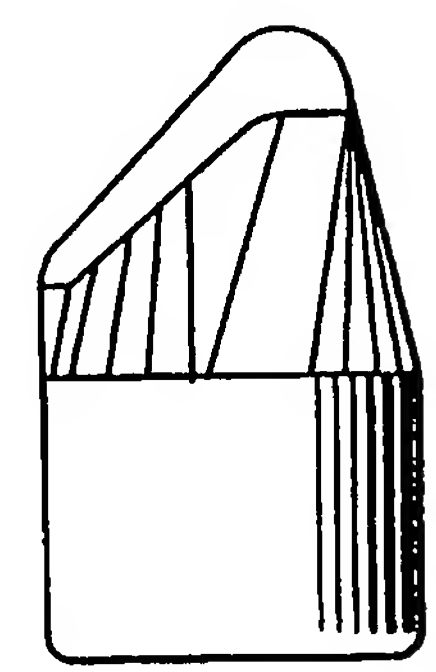

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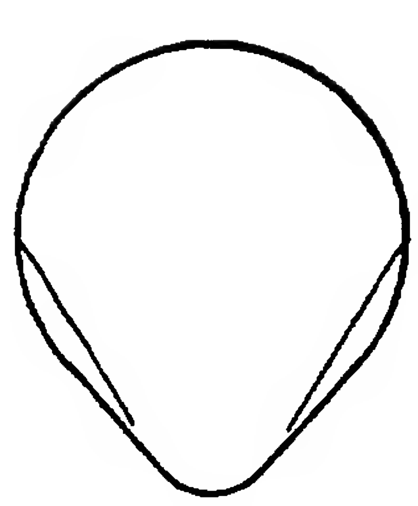

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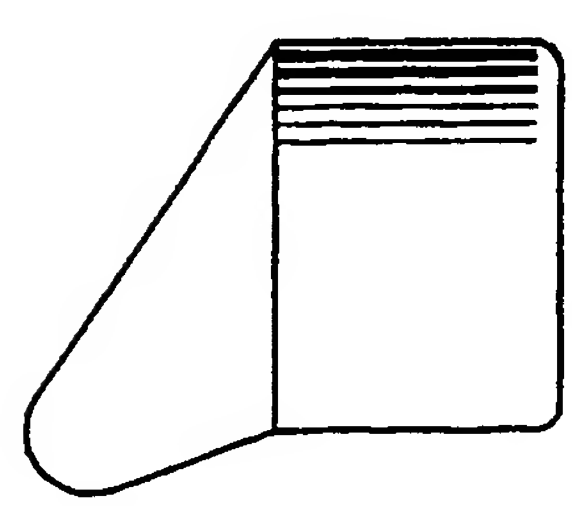

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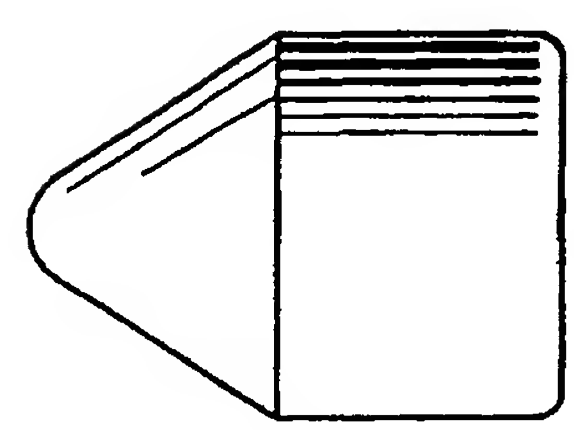

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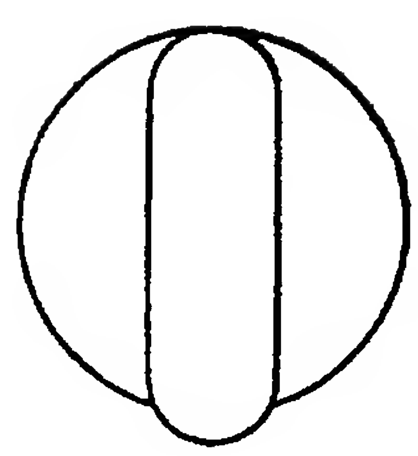

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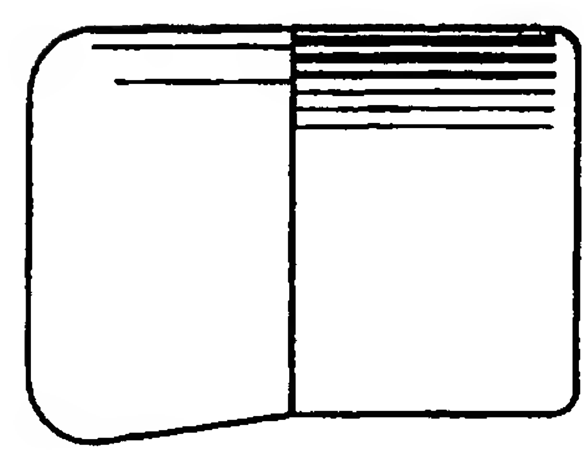

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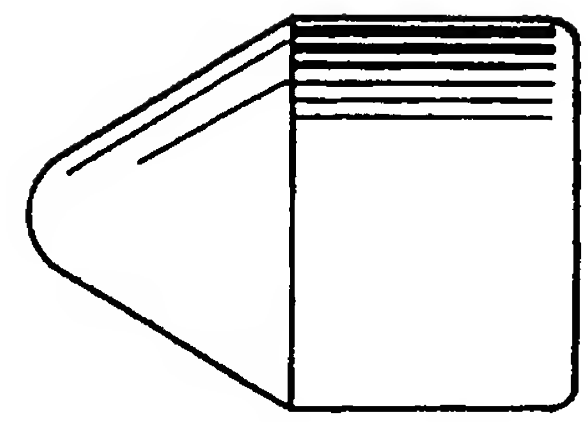

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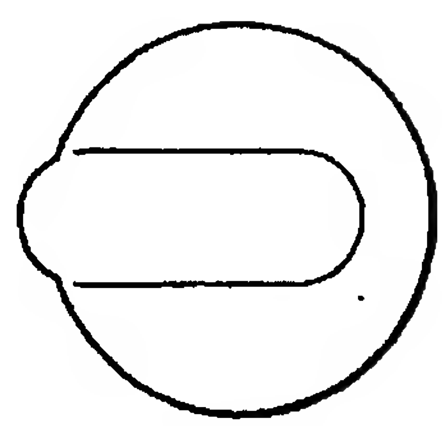

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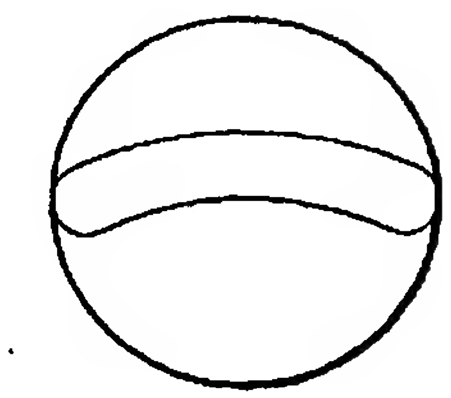

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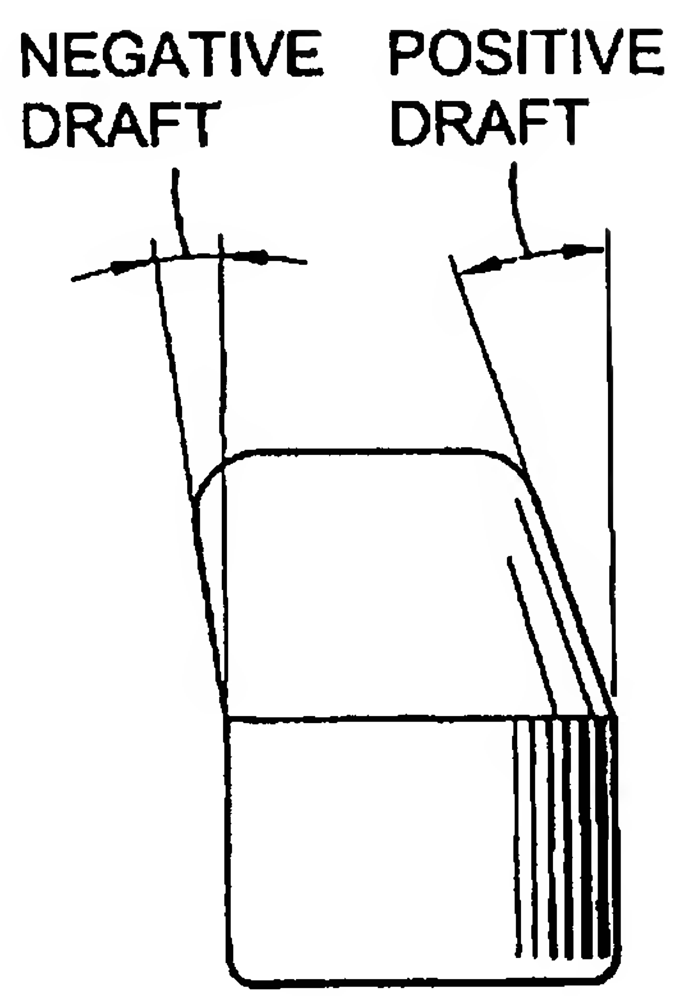

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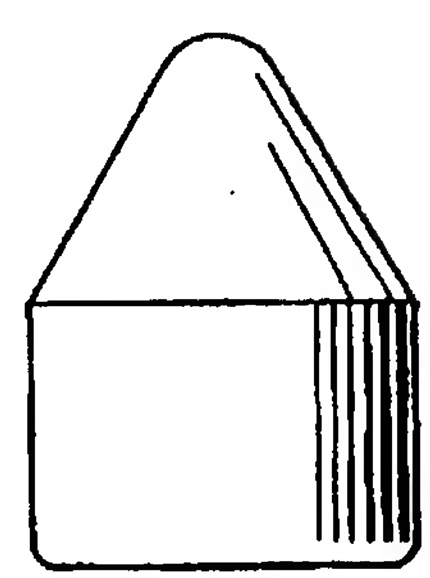

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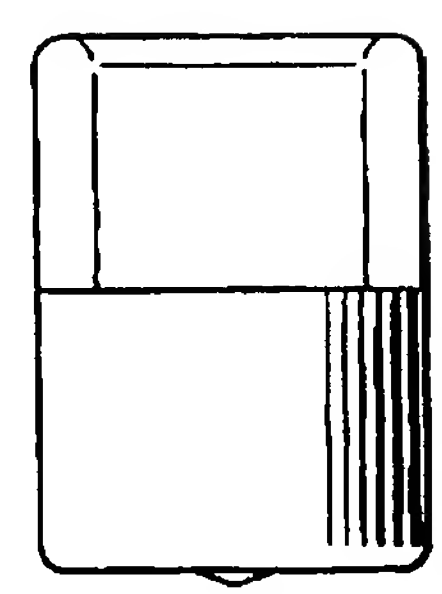

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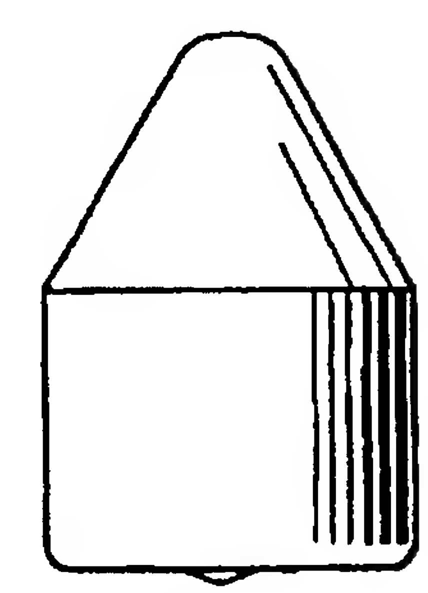

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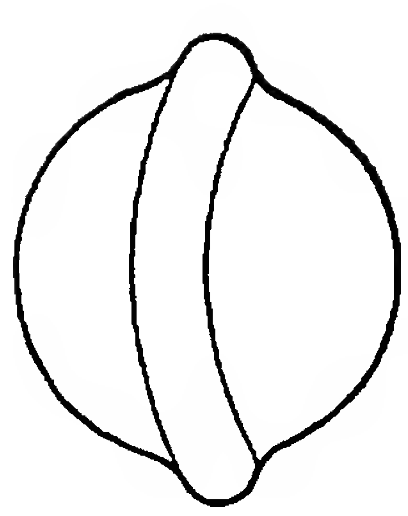

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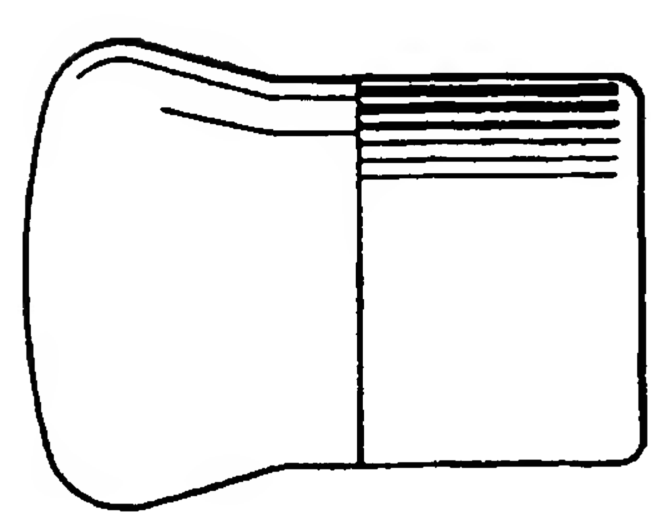

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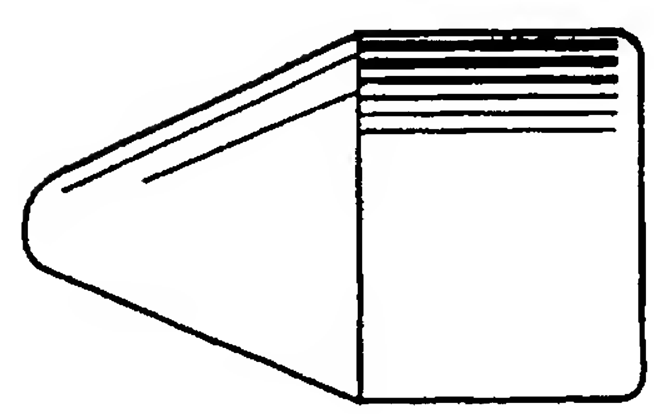

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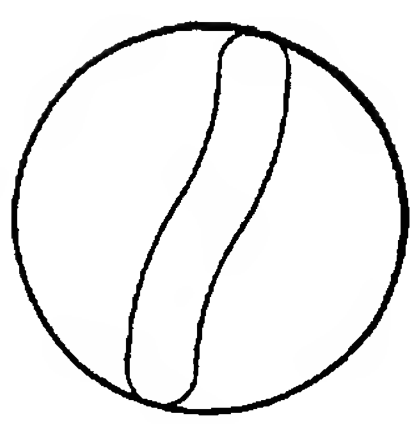

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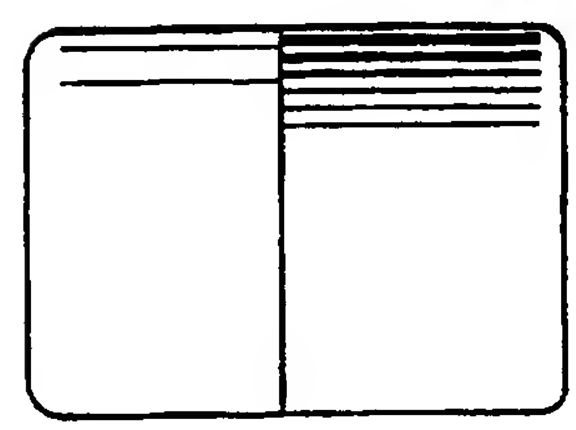

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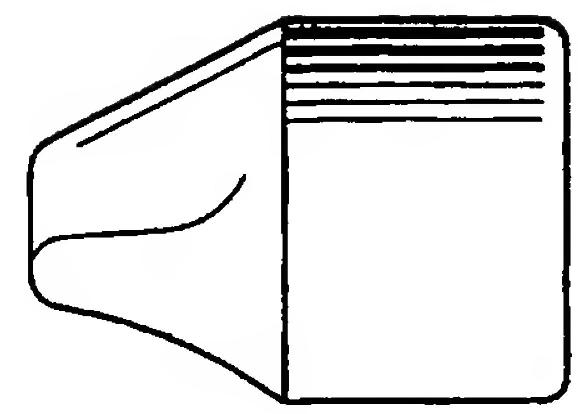

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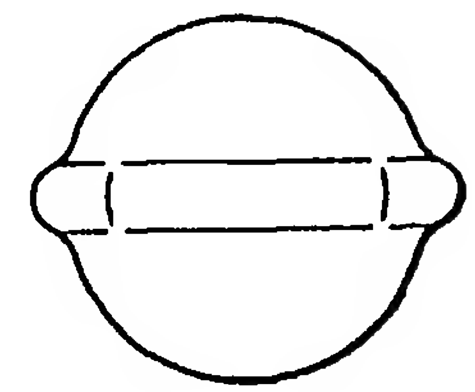

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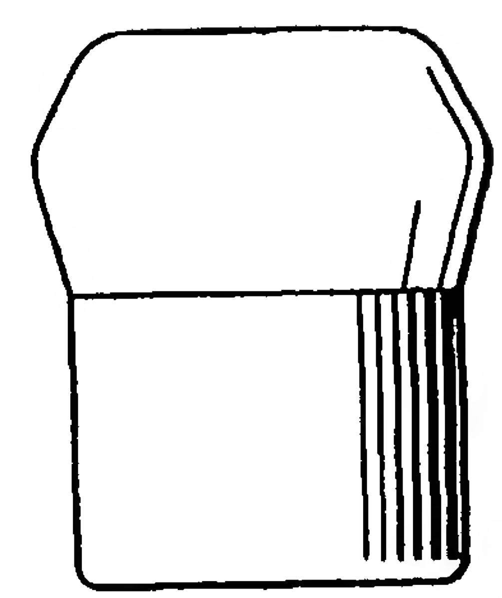

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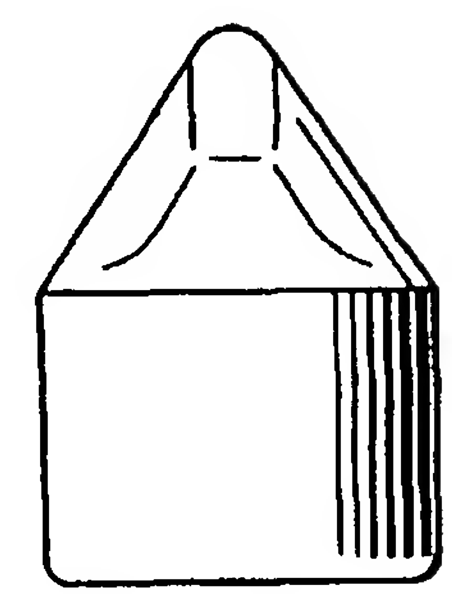

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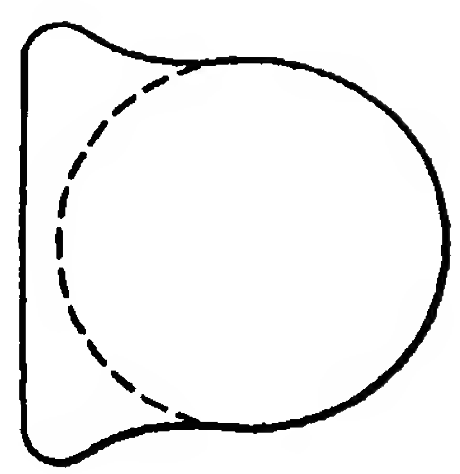

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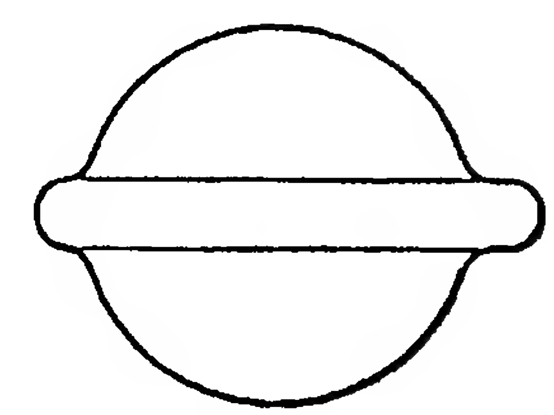

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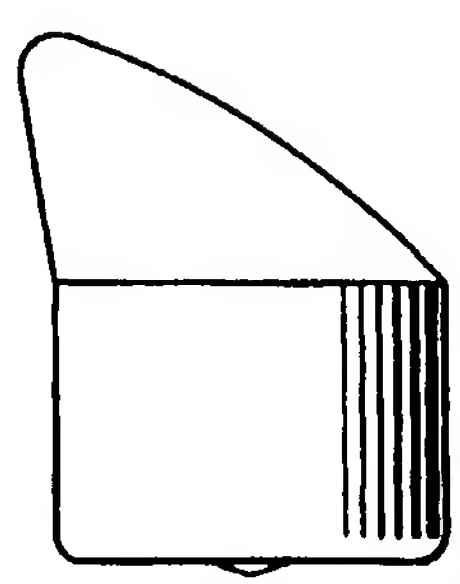

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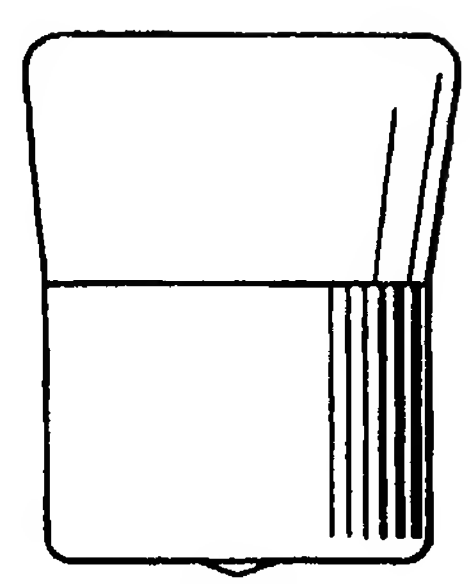

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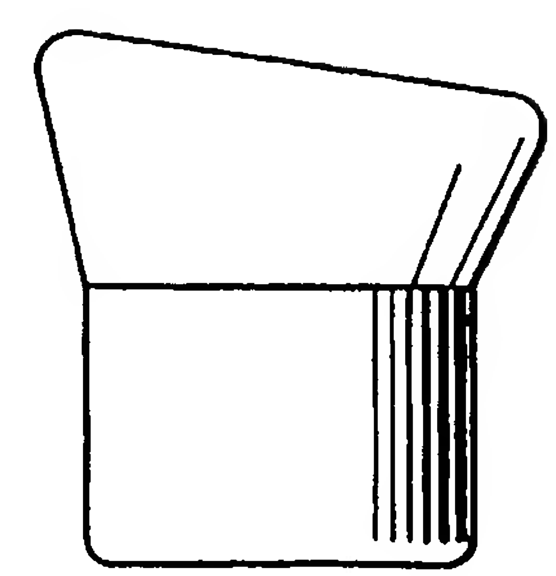

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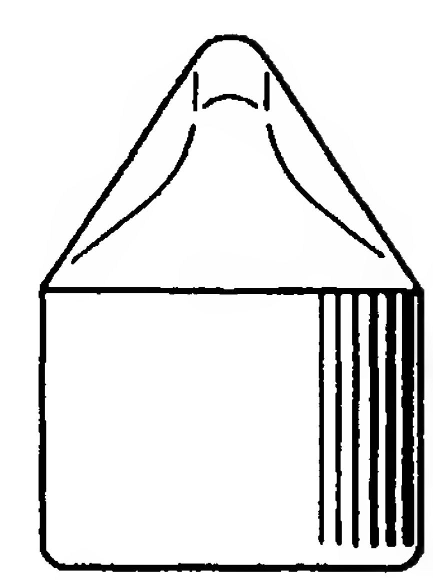

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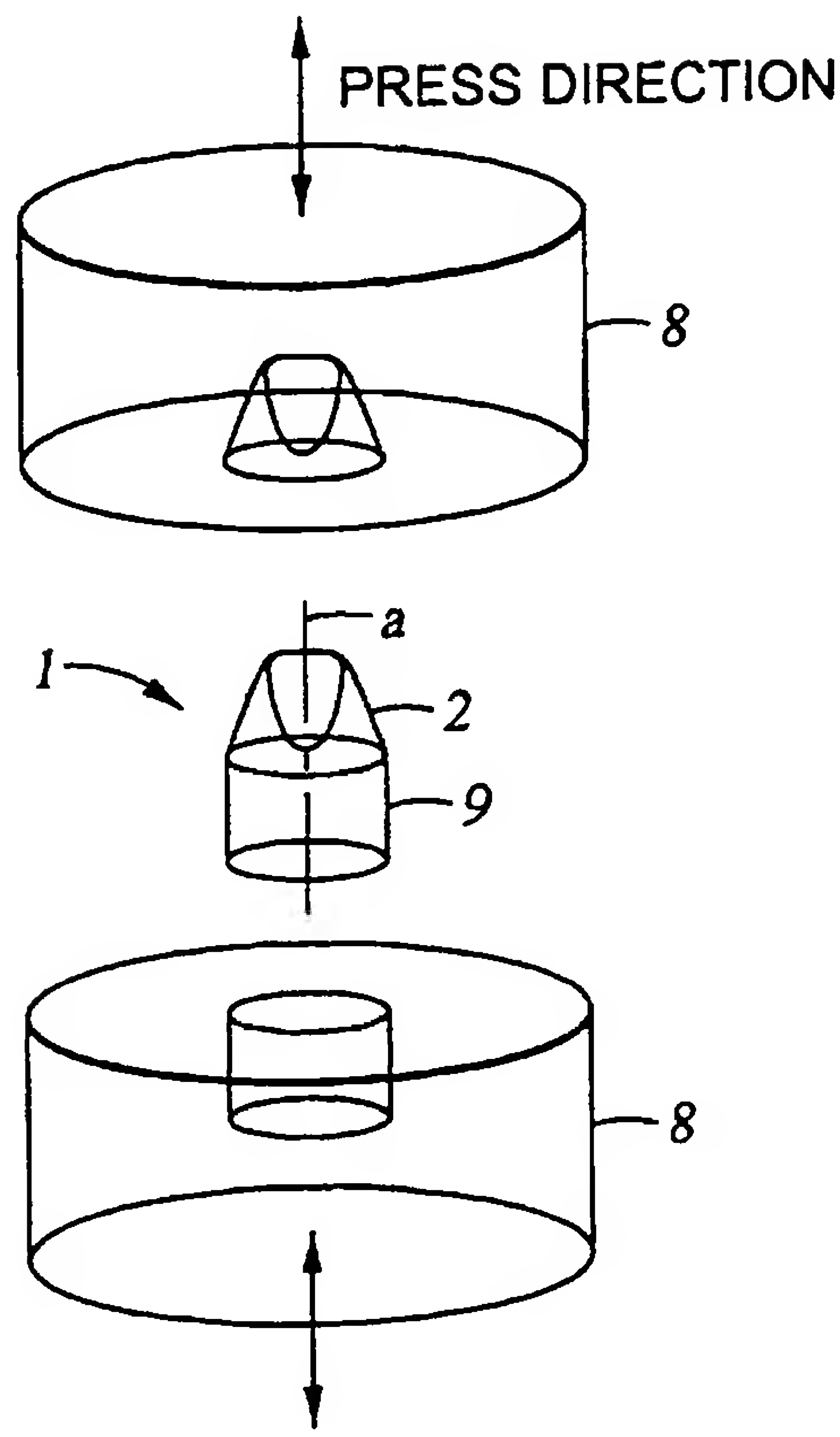

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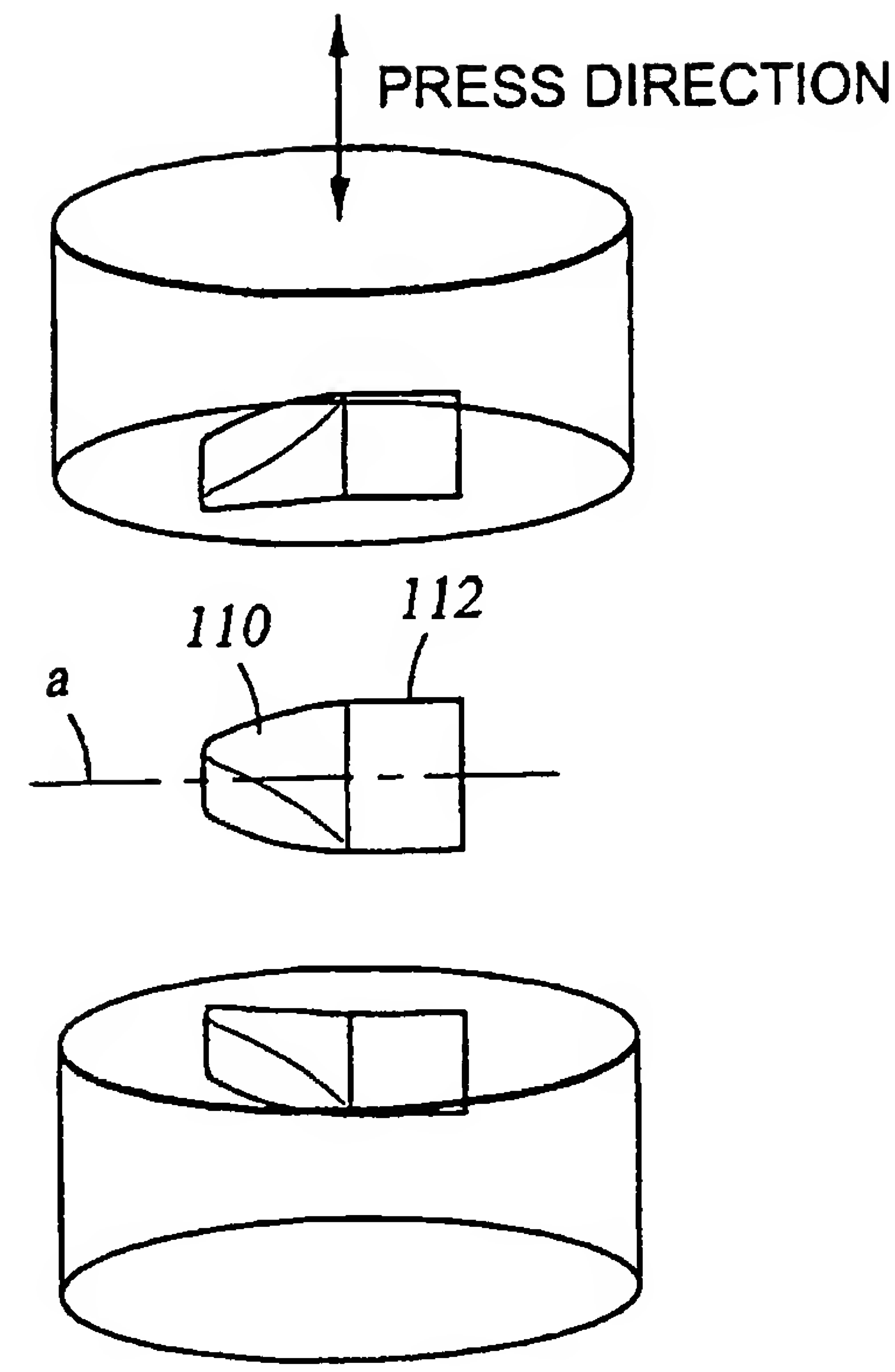

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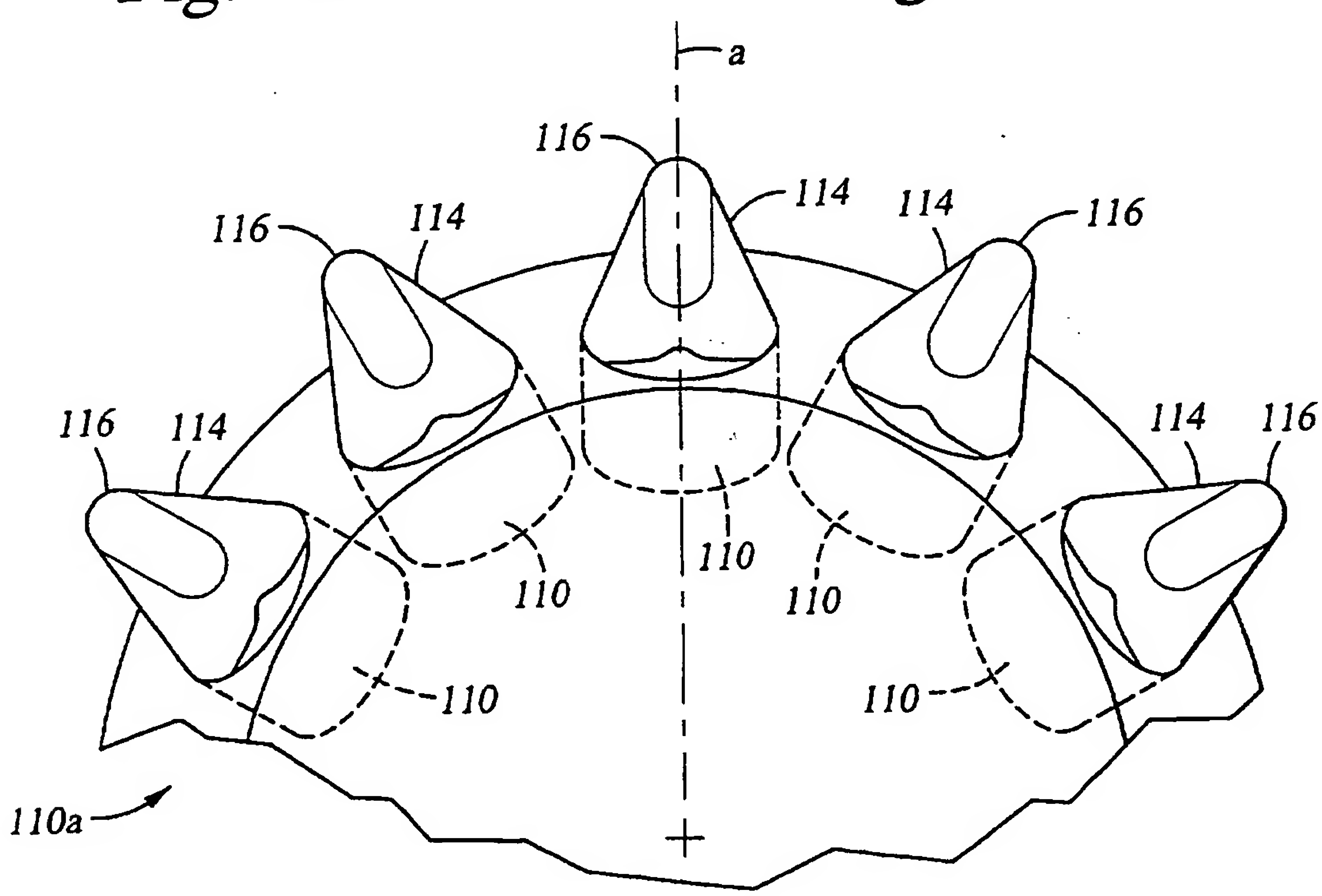

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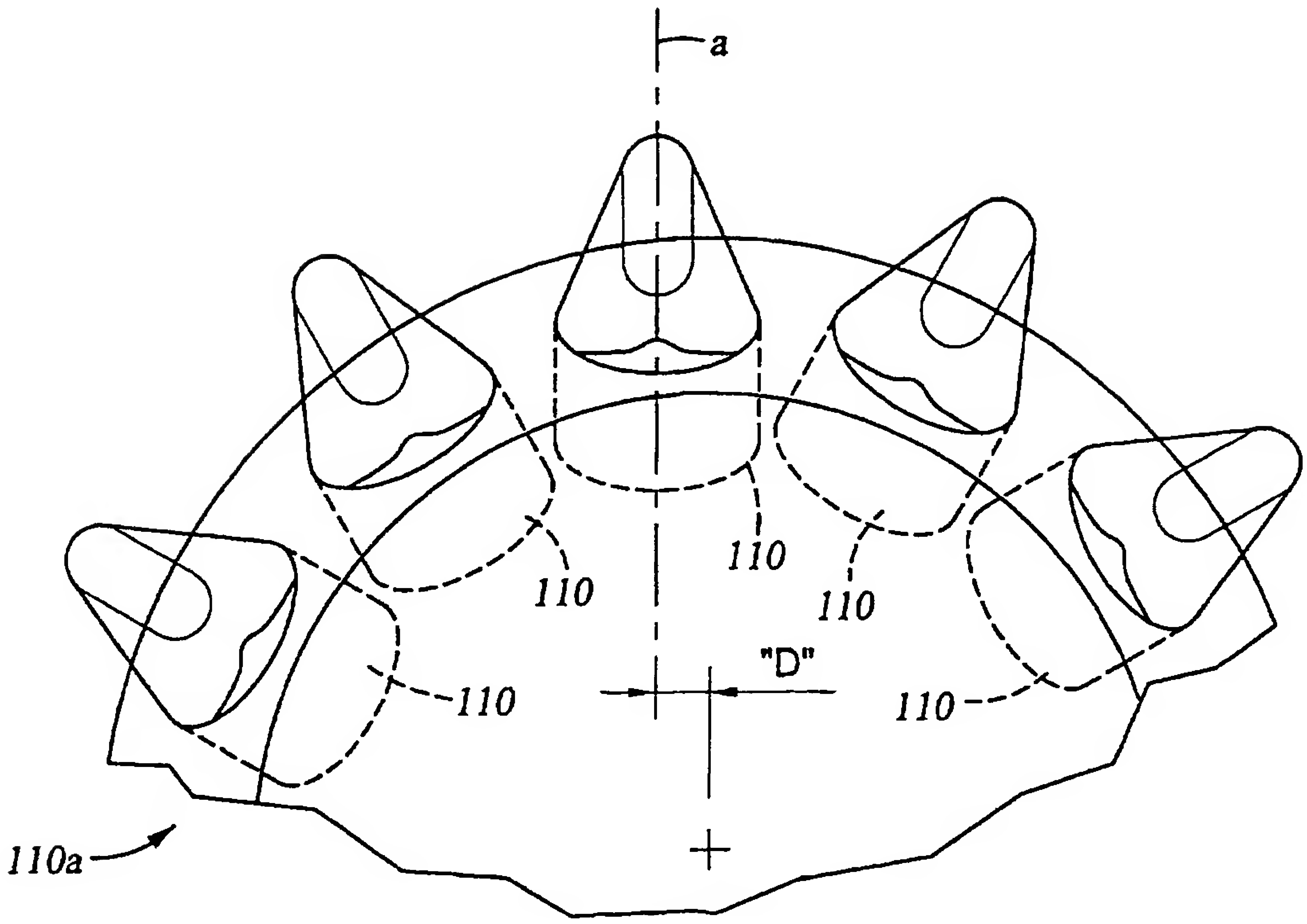

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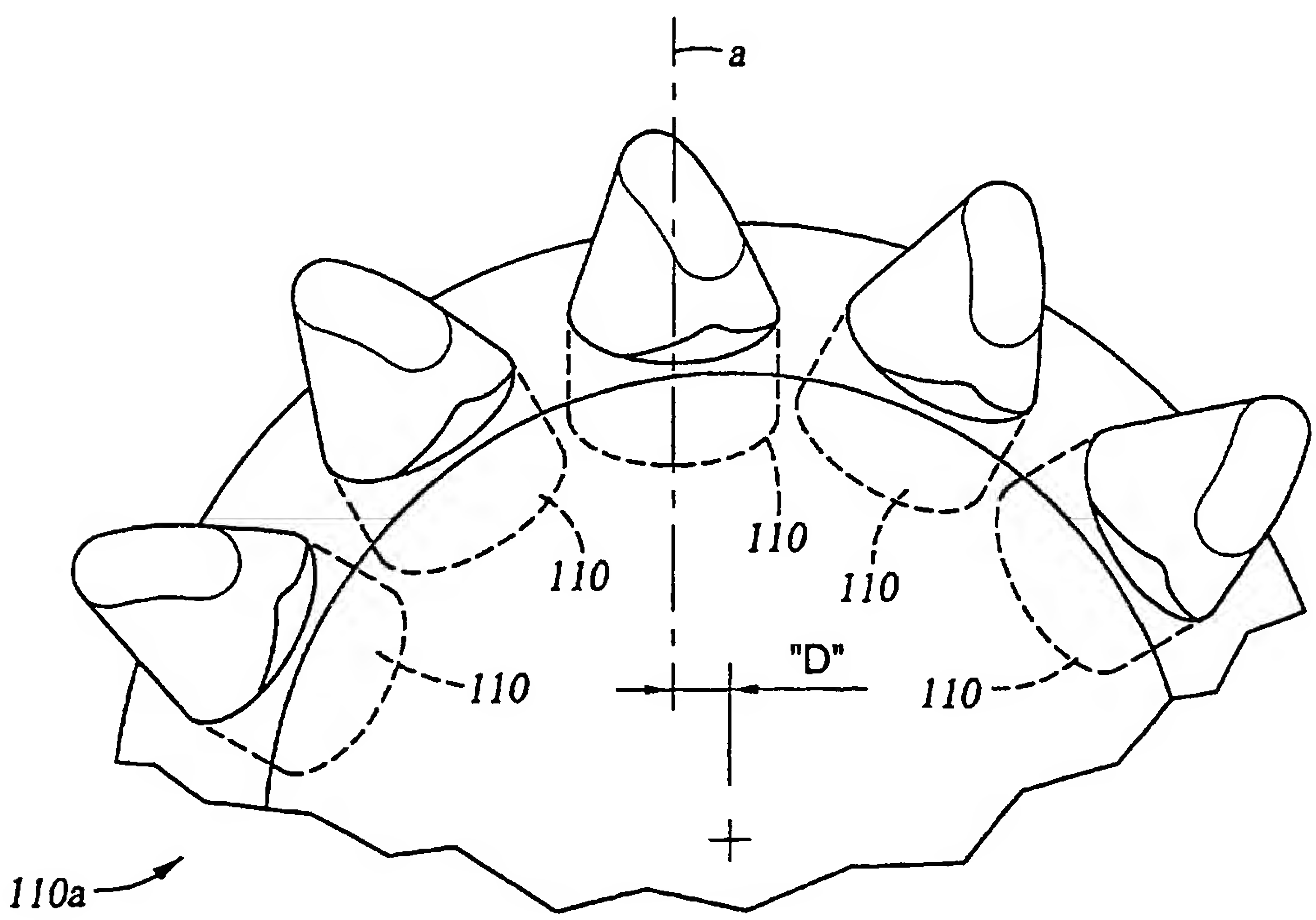

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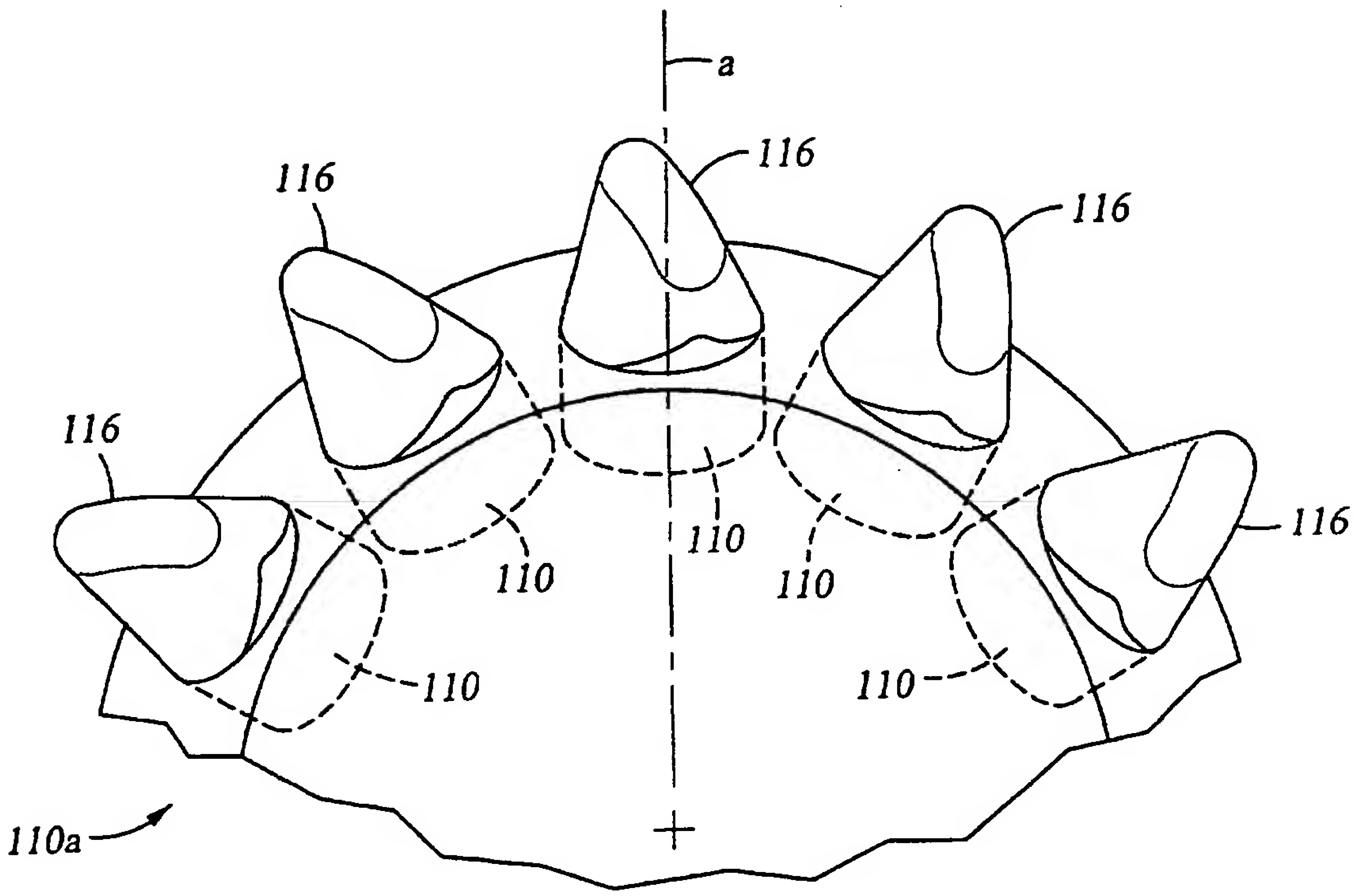

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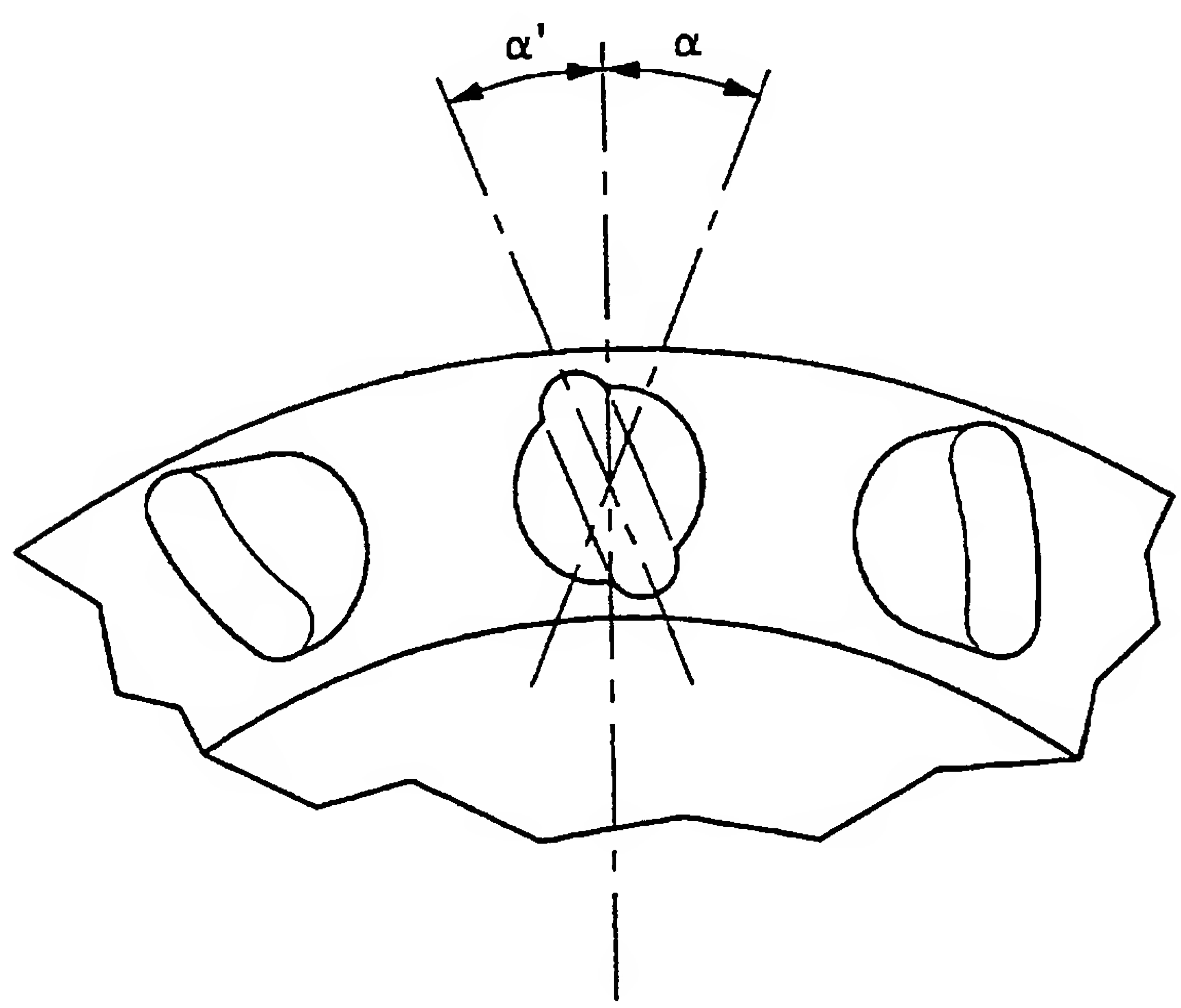

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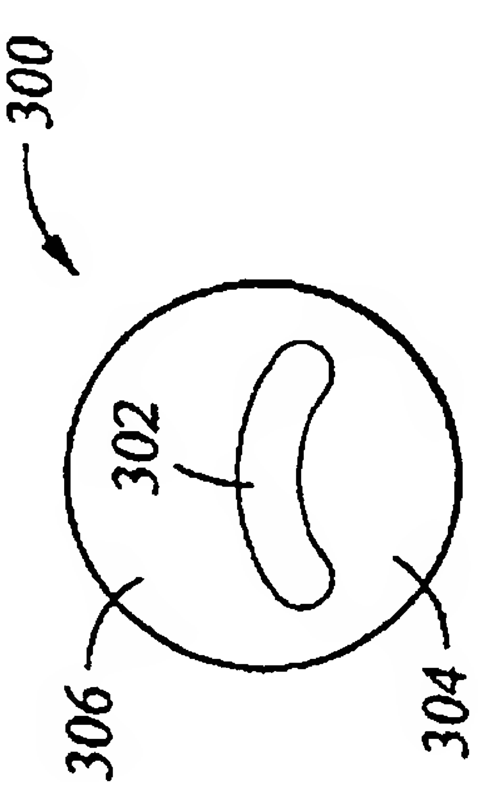

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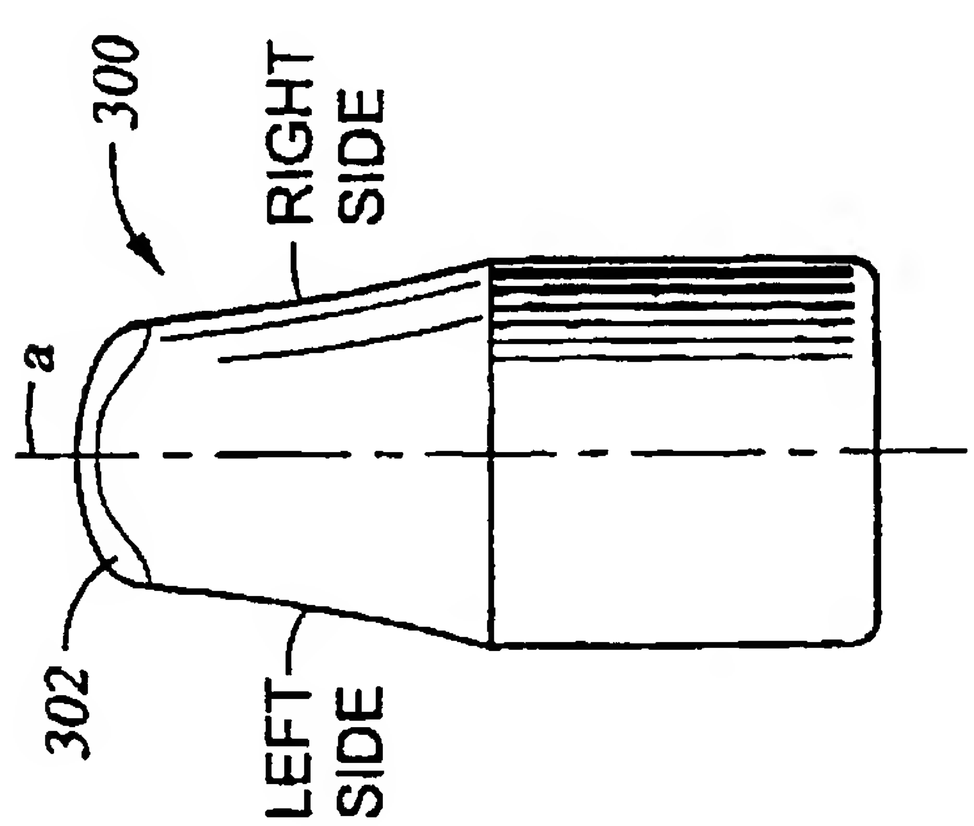

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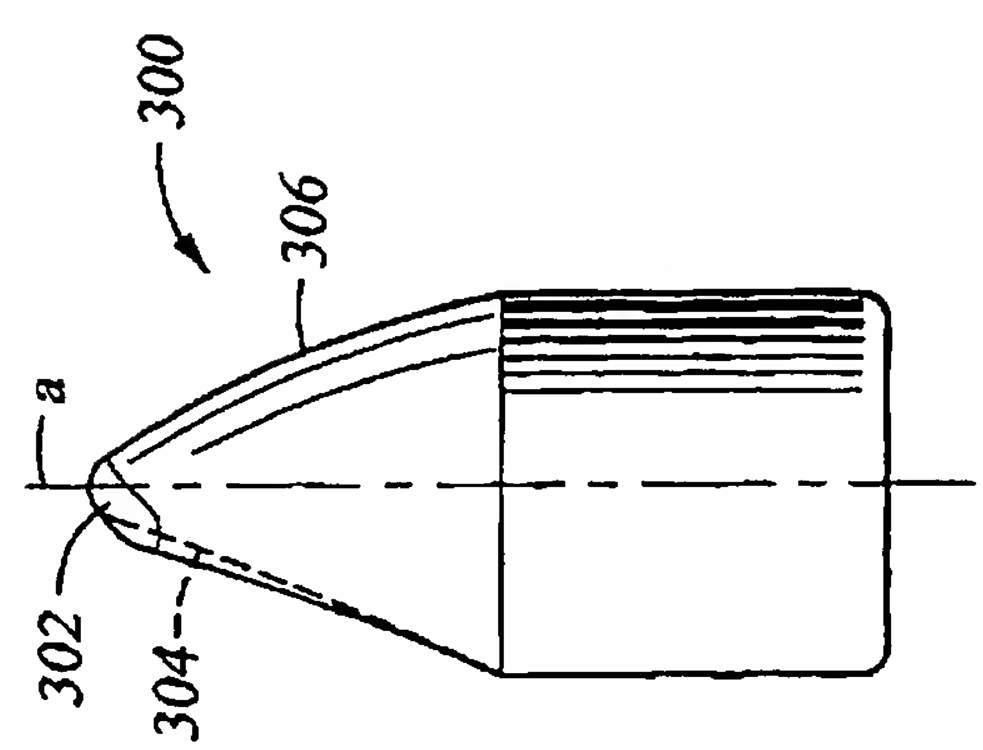
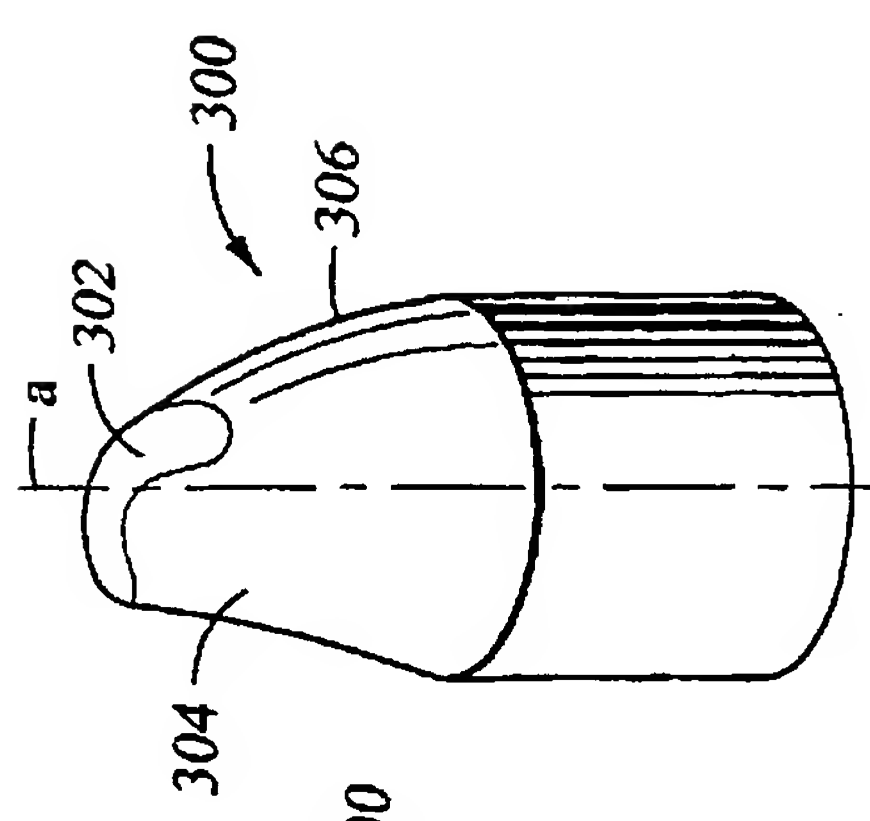


Fig. 25C



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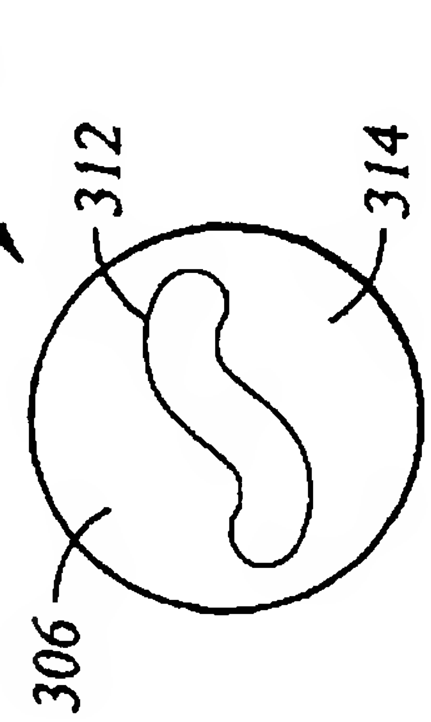

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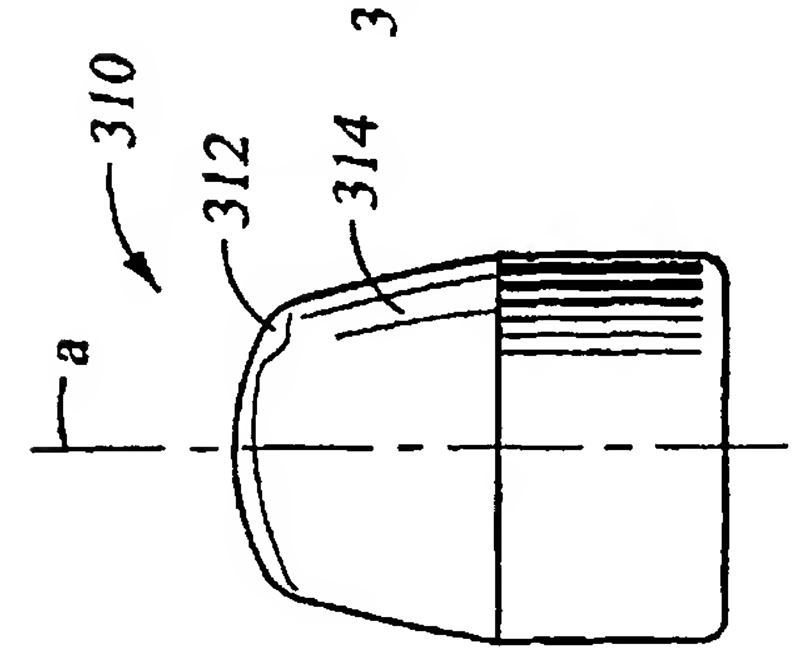

Fig. 26B

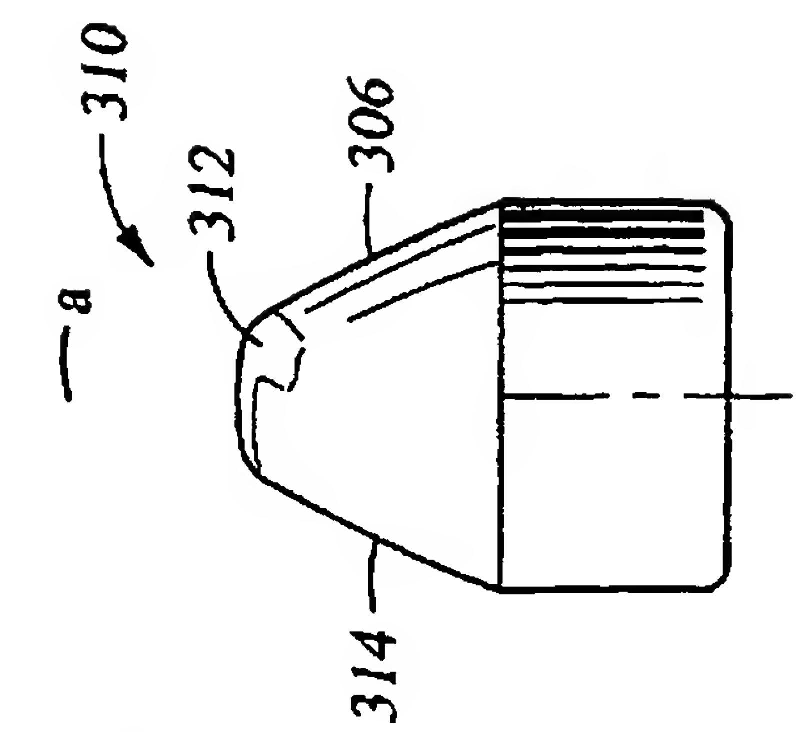

Fig. 26C

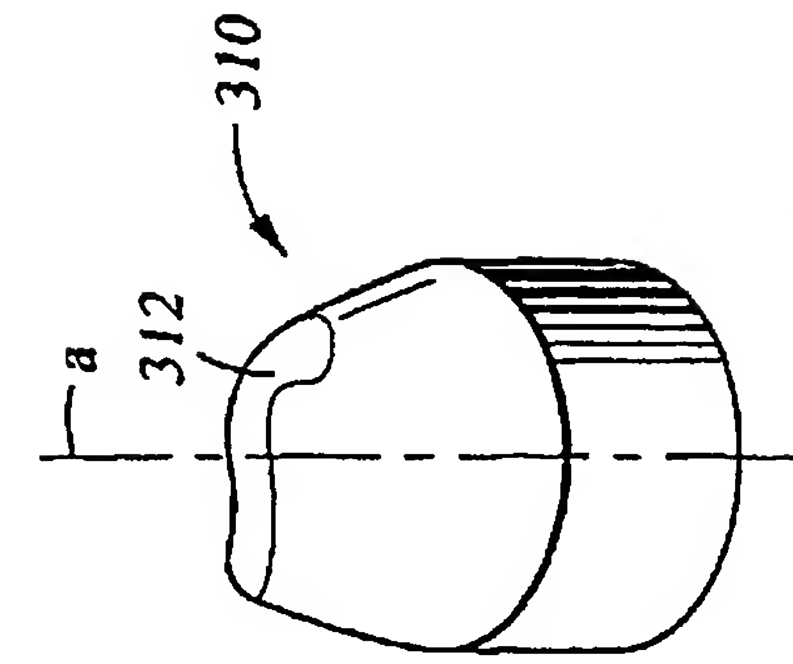

Fig. 26D

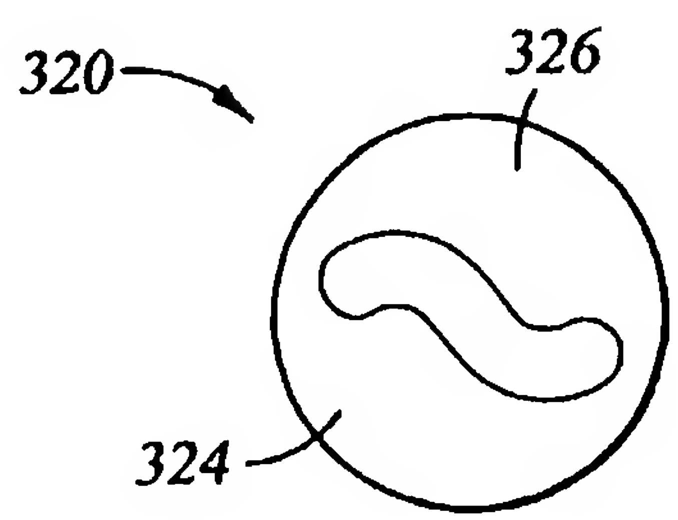

Fig. 27A

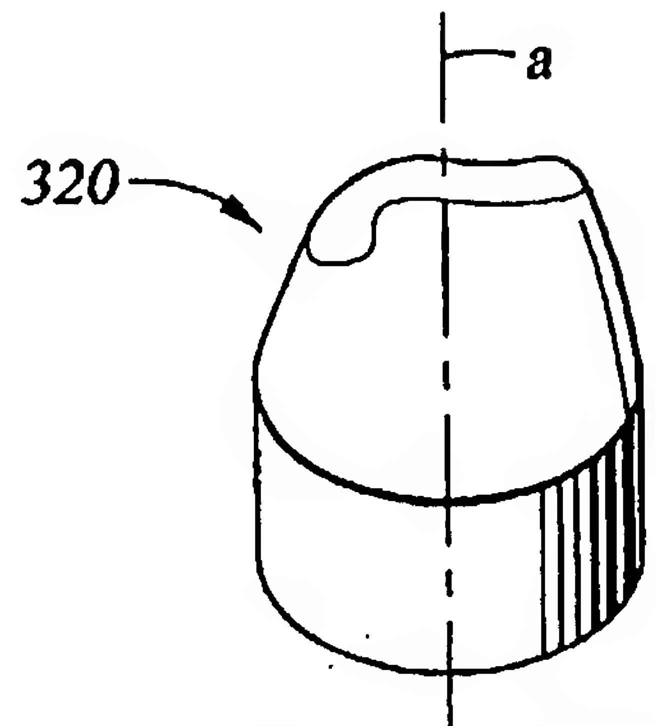

Fig. 27D

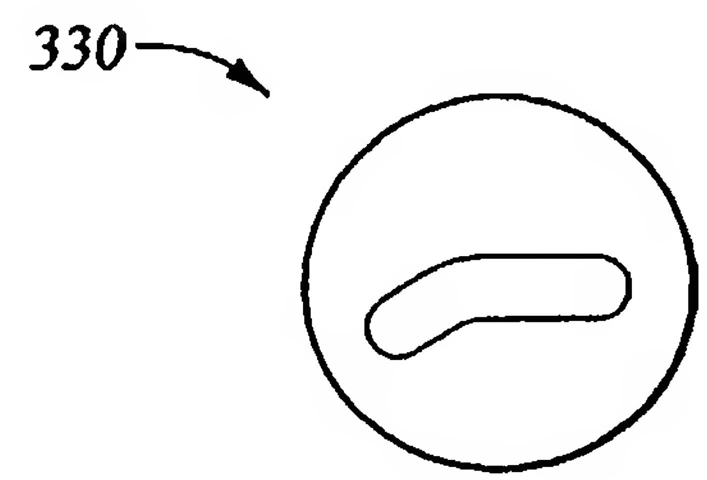

Fig. 28A

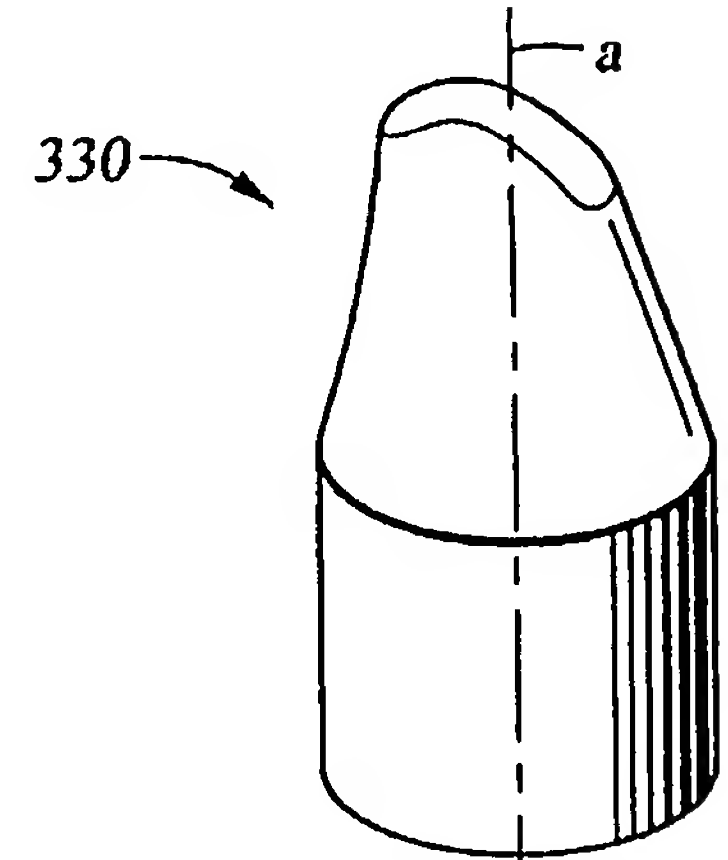

Fig. 28D

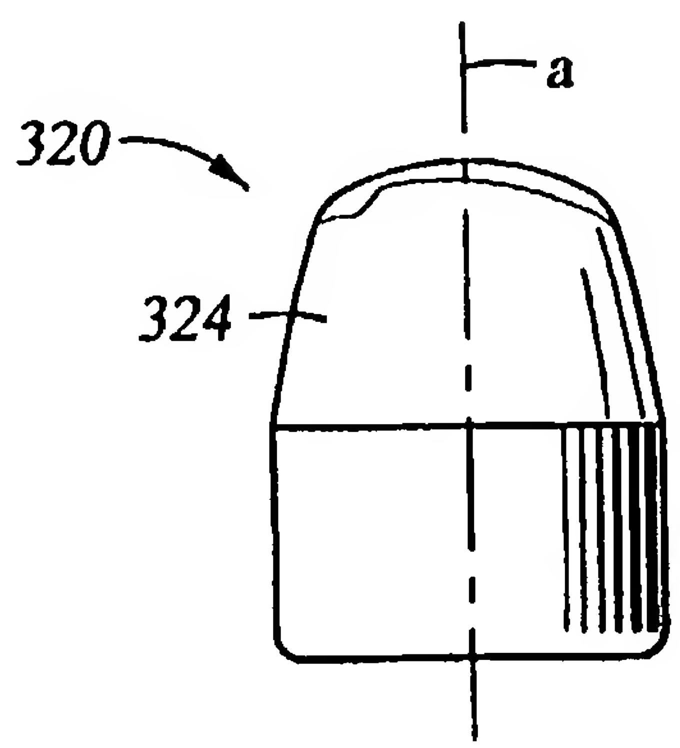

Fig. 27B

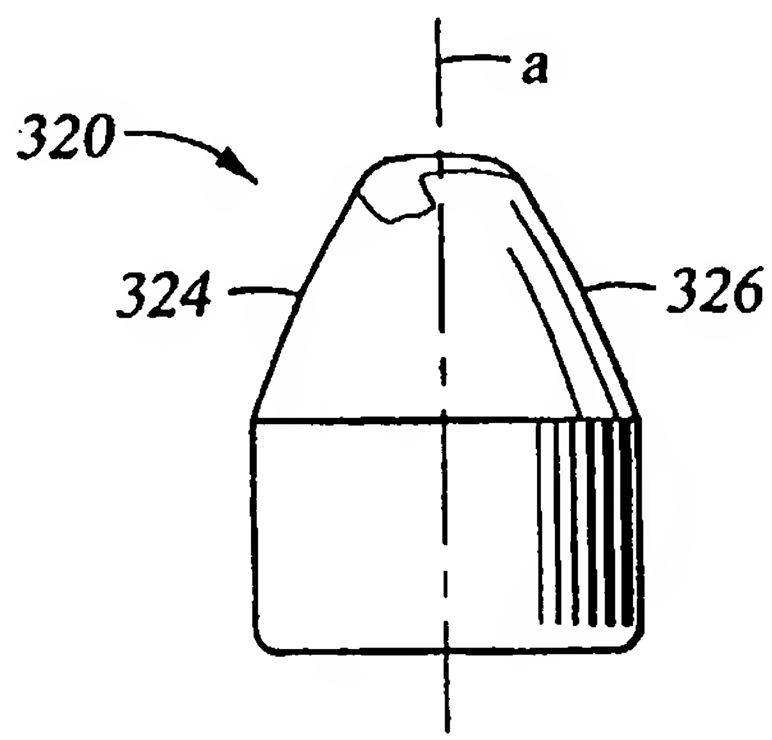

Fig. 27C

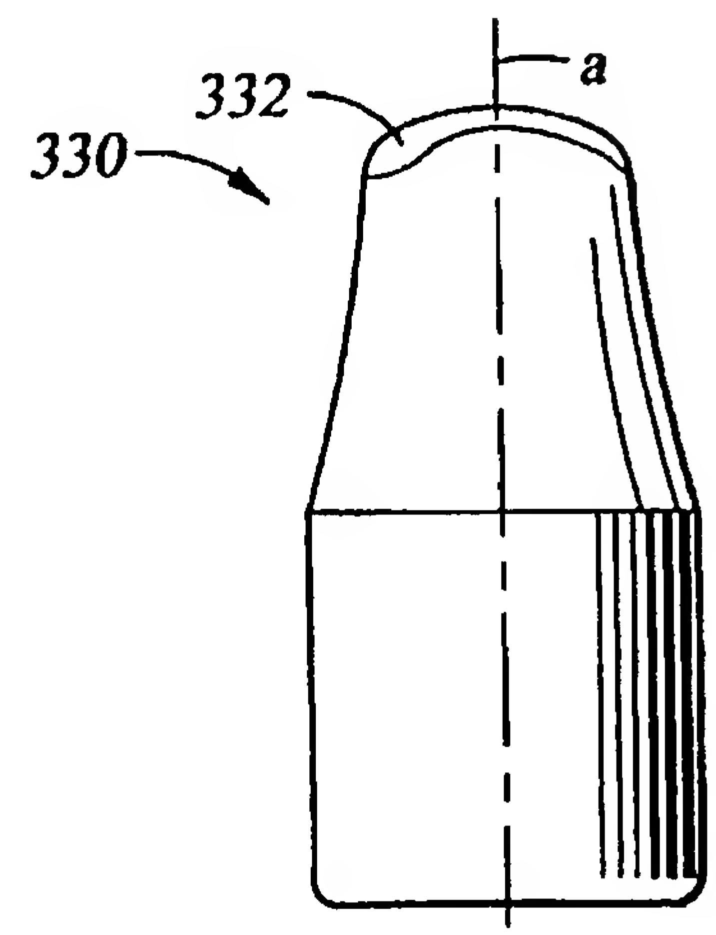

Fig. 28B

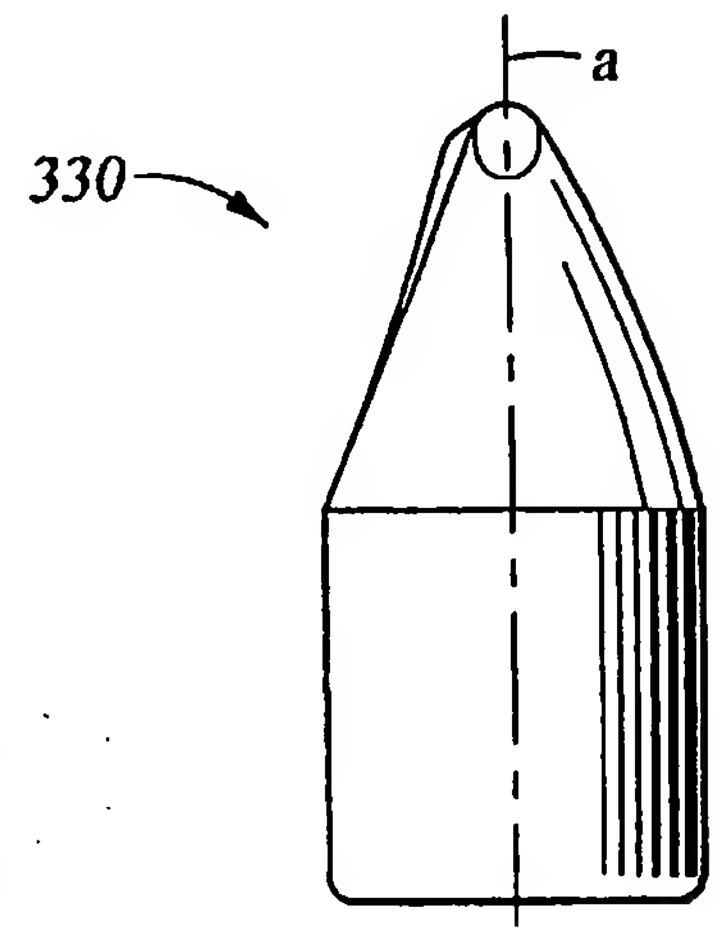

Fig. 28C

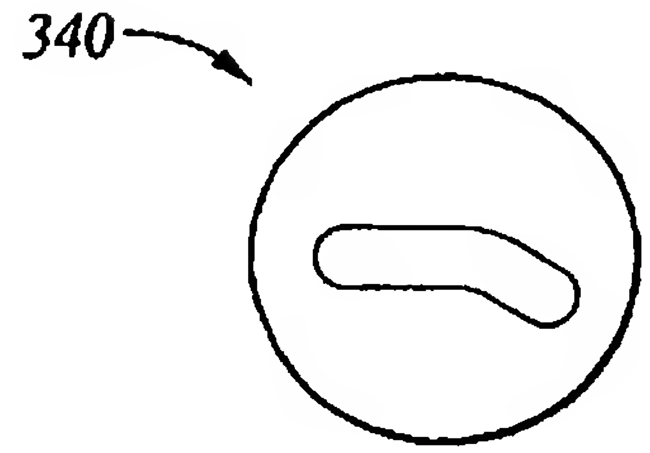

Fig. 29A

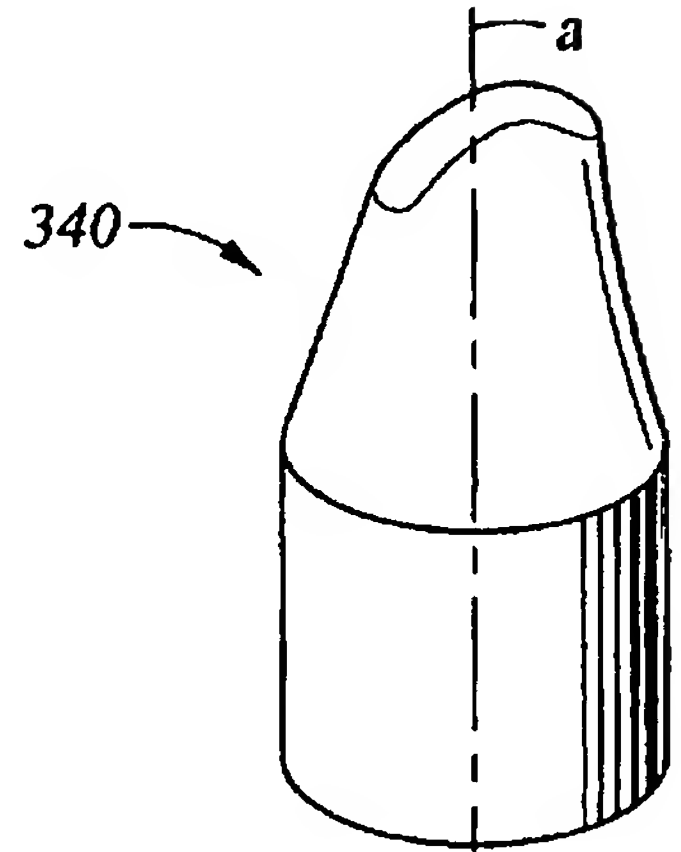

Fig. 29D

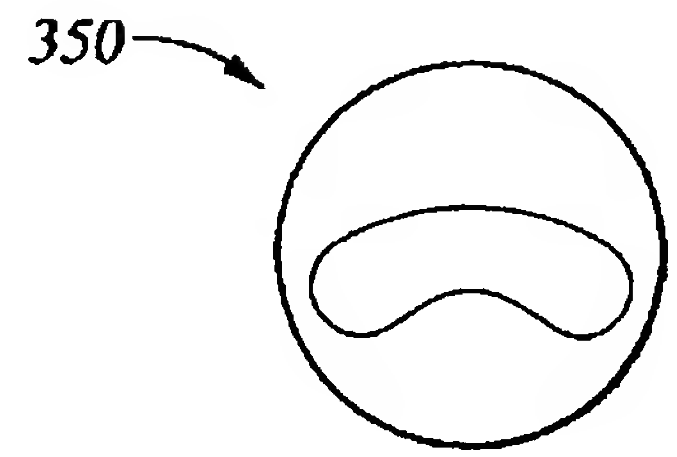

Fig. 30A

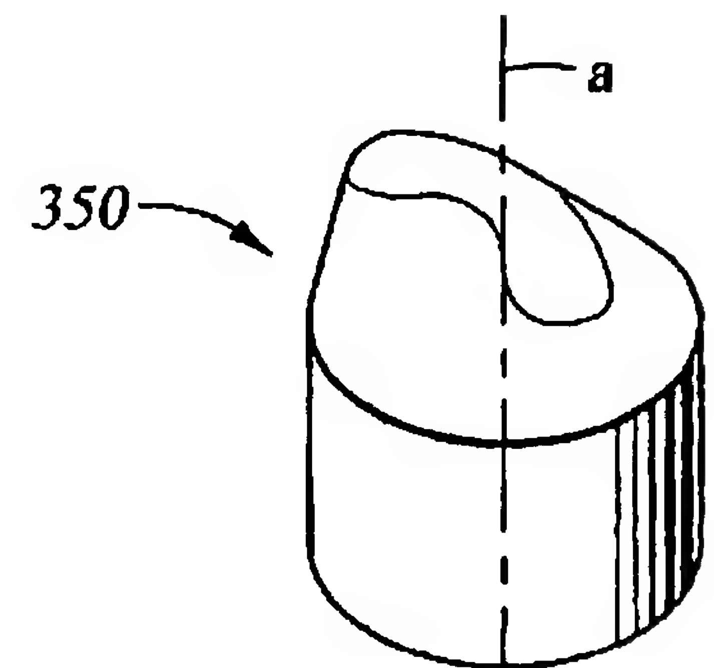

Fig. 30D

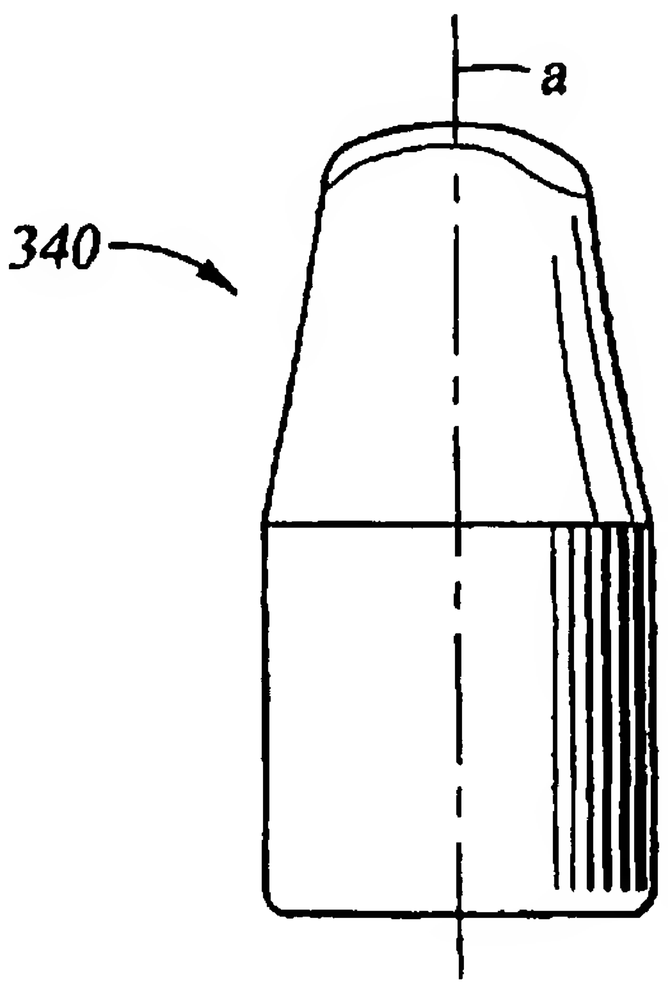

Fig. 29B

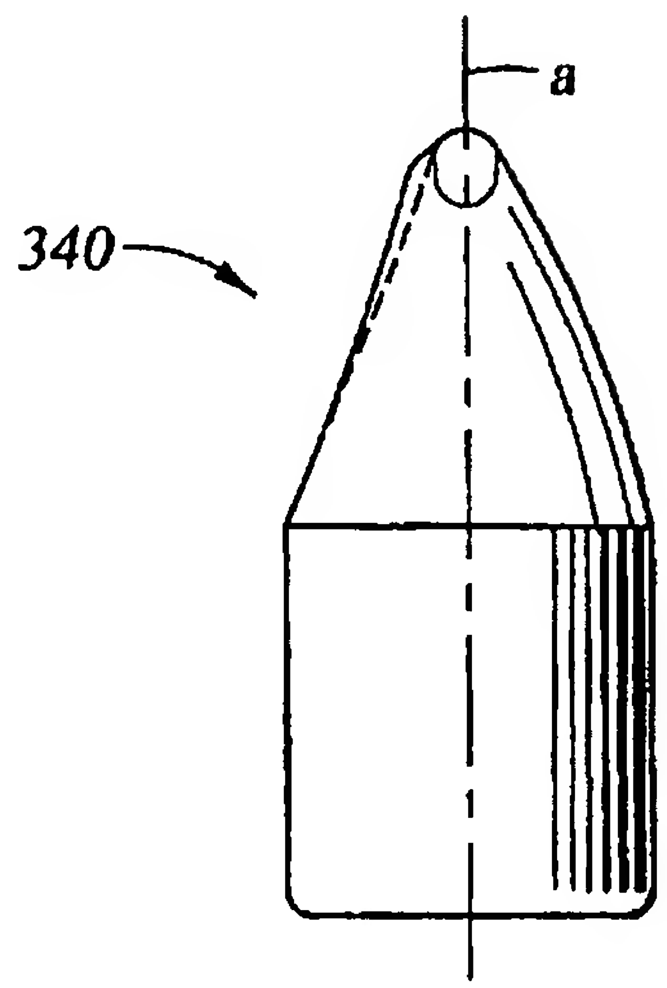

Fig. 29C

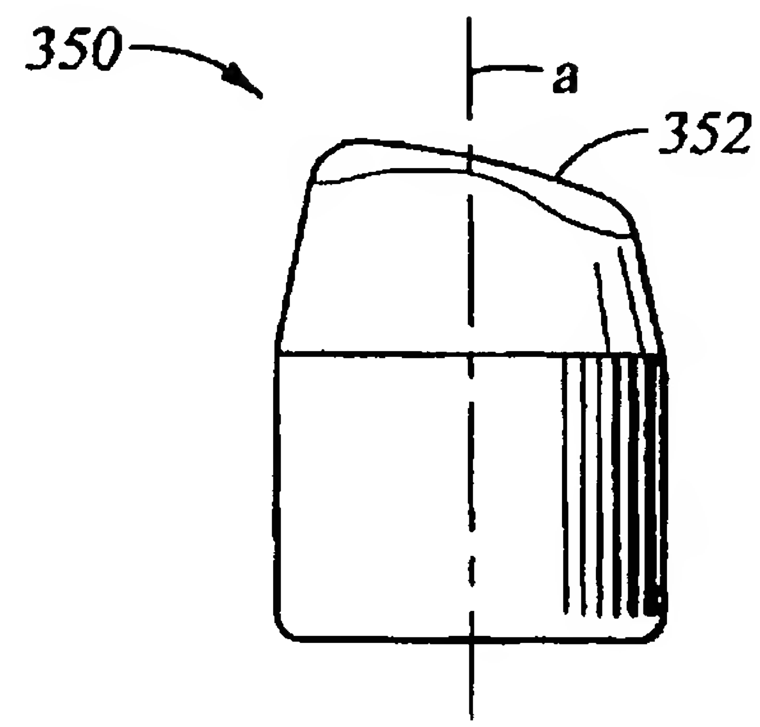

Fig. 30B

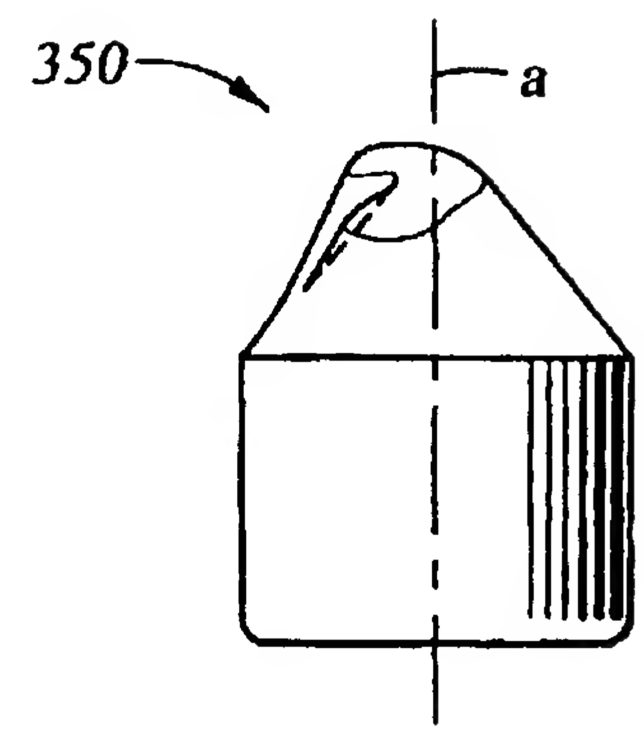

Fig. 30C

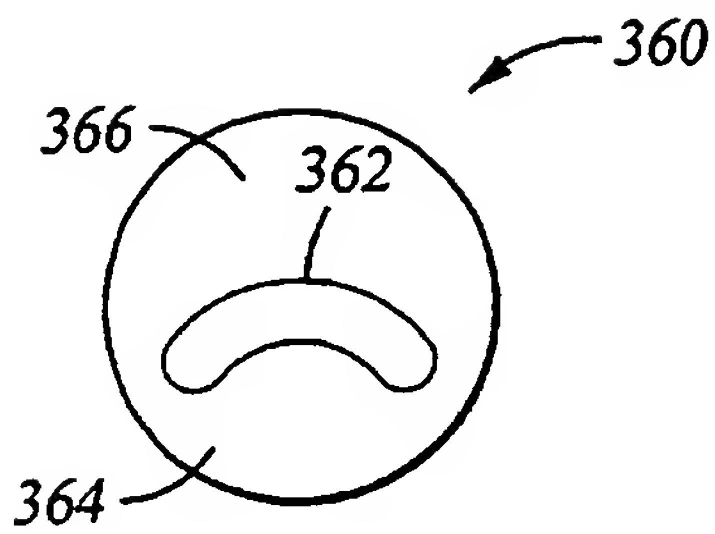

Fig. 31A

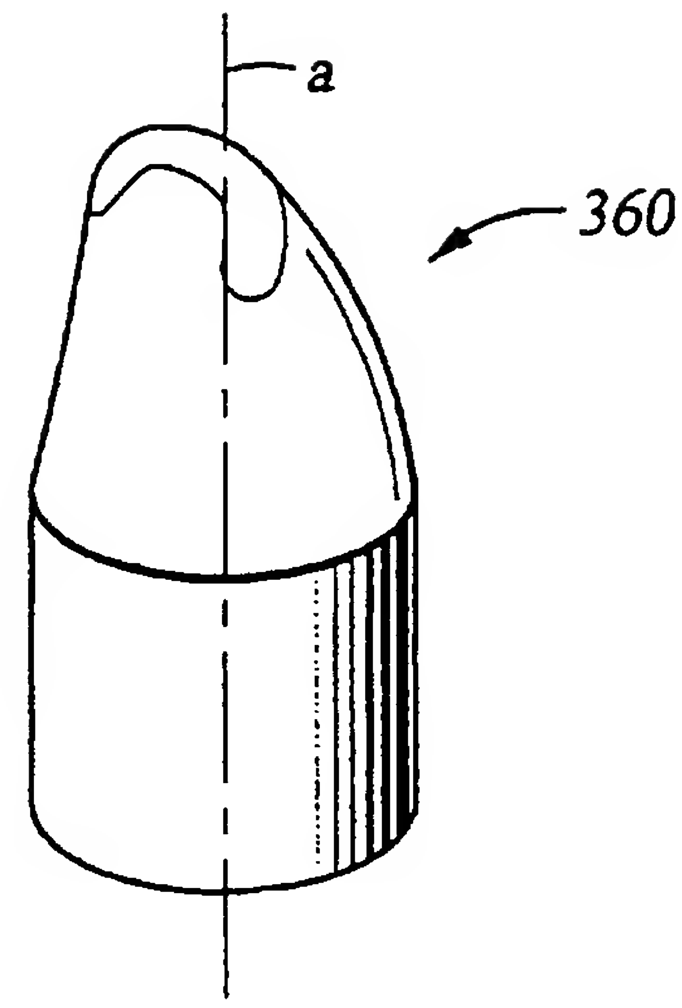

Fig. 31D

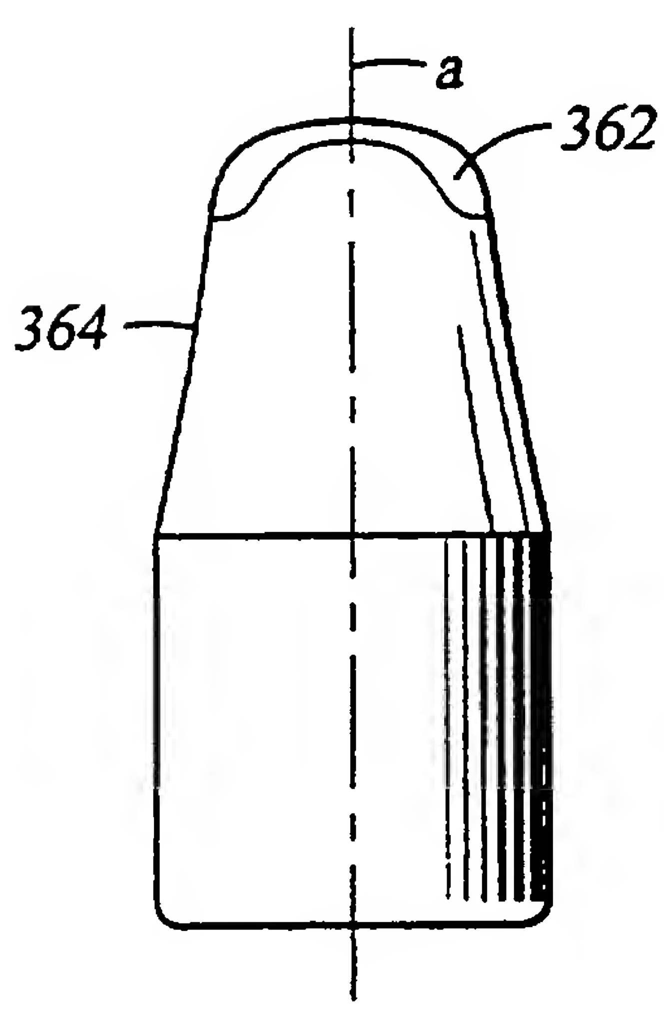

Fig. 31B

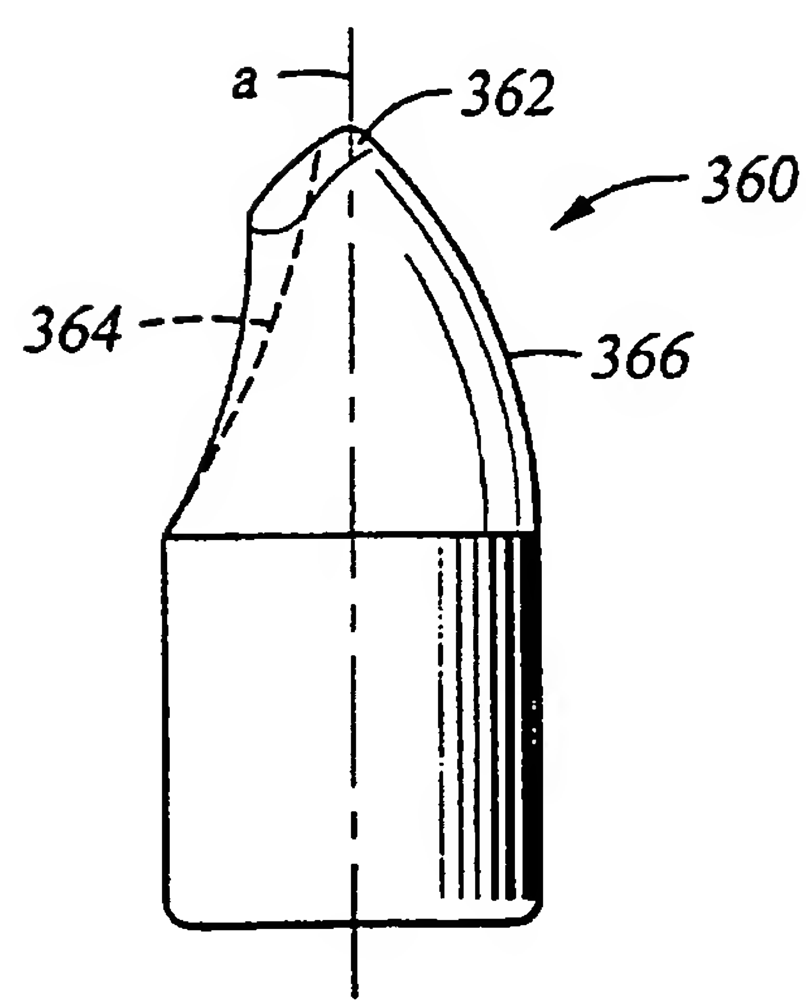

Fig. 31C

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DRILL BIT

The present invention relates to a drill bit. The invention relates generally to earth-boring bits used to drill a borehole for the ultimate recovery of oil, gas or minerals. More particularly, the invention relates to rolling cone rock bits and to an improved cutting structure for such bits. Still more particularly, the invention relates to a drill bit having a cutter element having a crest that is not a straight line when viewed along the longitudinal axis of the cutter element.

An earth-boring drill bit is typically mounted on the lower end of a drill string and is rotated by rotating the drill string at the surface or by actuation of downhole motors or turbines, or by both methods. With weight applied to the drill string, the rotating drill bit engages the earthen formation and proceeds to form a borehole along a predetermined path toward a target zone. The borehole formed in the drilling process will have a diameter generally equal to the diameter or "gage" of the drill bit.

A typical earth-boring bit includes one or more rotatable cutters that perform their cutting function due to the rolling movement of the cutters acting against the formation material. The cutters roll and slide upon the bottom of the borehole as the bit is rotated, the cutters thereby engaging and disintegrating the formation material in its path. The rotatable cutters may be described as generally conical in shape and are therefore sometimes referred to as rolling cones. Such bits typically include a bit body with a plurality of journal segment legs. The rolling cone cutters are mounted on bearing pin shafts that extend downwardly and inwardly from the journal segment legs. The borehole is formed as the gouging and scraping or crushing and chipping action of the rotary cones remove

chips of formation material which are carried upward and out of the borehole by drilling fluid which is pumped downwardly through the drill pipe and out of the bit.

The earth-disintegrating action of the rolling cone cutters is enhanced by providing the cutters with a plurality of cutter elements. Cutter elements are generally two types: inserts formed of a very hard material, such as cemented tungsten carbide, that are press fit into undersized apertures or similarly secured in the cone surface; or teeth that are milled, cast or otherwise integrally formed from the material of the rolling cone. Bits having tungsten carbide inserts are typically referred to as "TCI" bits.

The cutting surfaces of inserts are, in some instances, coated with a very hard "superabrasive" coating such as polycrystalline diamond (PCD) or cubic boron nitride (PCBN). Superabrasive materials are significantly harder than cemented tungsten carbide. As used herein, the term "superabrasive" means a material having a hardness of at least 2,700 Knoop (kg/mm^2). Conventional PCD grades have a hardness range of about 5,000-8,000 Knoop, while PCBN grades have a hardness range of about 2,700-3,500 Knoop. By way of comparison, a typical cemented tungsten carbide grade used to form cutter elements has a hardness of about 1475 Knoop. In each case, the cutter elements on the rotating cutters functionally break up the formation to create new borehole by a combination of gouging and scraping or chipping and crushing.

The cost of drilling a borehole is proportional to the length of time it takes to drill to the desired depth and location. In oil and gas drilling, the time required to drill the well, in turn, is greatly affected by the number of times the drill bit must be changed in order to reach

the targeted formation. This is the case because each time the bit is changed, the entire string of drill pipe, which may be miles long, must be retrieved from the borehole, section by section. Once the drill string has been retrieved and the new bit installed, the bit must be lowered to the bottom of the borehole on the drill string, which again must be constructed section by section. As is thus obvious, this process, known as a "trip" of the drill string, requires considerable time, effort and expense. Accordingly, it is always desirable to employ drill bits which will drill faster and longer and which are usable over a wider range of formation hardness.

The length of time that a drill bit may be employed before it must be changed depends upon its rate of penetration ("ROP"), as well as its durability or ability to maintain an acceptable ROP. The form and positioning of the cutter elements on the cone cutters greatly impact bit durability and ROP and thus are critical to the success of a particular bit design.

Bit durability is, in part, measured by a bit's ability to "hold gage", meaning its ability to maintain a full gage borehole diameter over the entire length of the borehole. To assist in maintaining the gage of a borehole, conventional rolling cone bits typically employ a heel row of hard metal inserts on the heel surface of the rolling cone cutters. The heel surface is a generally frustoconical surface and is configured and positioned so as to generally align with and ream the sidewall of the borehole as the bit rotates. The inserts in the heel surface contact the borehole wall with a sliding motion and thus generally may be described as scraping or reaming the borehole sidewall.

In addition to the heel row inserts, conventional bits typically include a primary "gage" row of cutter elements mounted adjacent to the heel surface but oriented and sized so as to cut the corner as well as the bottom of the borehole. Conventional bits can also contain a secondary gage trimming row or a nestled gage row with lesser extension to assist in trimming the bore hole wall. Conventional bits also include a number of additional rows of cutter elements that are located on the cones in rows disposed radially inward from the gage row. These cutter elements are sized and configured for cutting the bottom of the borehole and are typically described as primary "inner row" cutter elements. Together, the primary gage and primary inner row cutter elements of the bit form the "primary rows". Primary row cutter elements are the cutter elements that project the most outwardly from the body of the rolling cone for cutting the bore hole bottom.

A review of post run bit performance data from 1991 through 1995 indicated that most aggressive roller cone cutting structures from both milled tooth and tungsten carbide insert bits were sub-optimal at addressing very soft rock formations (i.e. less than 2000 psi (approximately 14 MPa) unconfined rock compressive strength). Ultra-soft to soft formations typically consist of clays, claystones, very soft shales, occasionally limy marls, and dispersed or unconsolidated sands, and typically exhibit plastic behaviour. Very soft or weak clays/shales vary in their mechanical response from more competent (harder) shales, under the same compression loads, as applied in rotary rock bit drilling. Soft shales respond plastically, or simply deform under the applied load, as opposed to a brittle failure or rupture (crack) formed in more competent rocks to create the cutting or chip. In these very soft/plastic formation applications, it is not possible to rely on conventional brittle rock failure

modes, where cracks propagate from the loaded tooth penetration crater to the adjacent tooth craters, to create a chip or cutting. For this reason, the cutting structure arrangement must mechanically gouge away a large percentage of the hole bottom in order to drill efficiently. In these types of formations, maximum mechanical efficiency is accomplished by maximising the bottom hole coverage of the inserts contacting the hole bottom per revolution so as to maximise the gouging and scraping action.

According to a first aspect of the present invention, there is provided a drill bit, the bit comprising: a bit body; at least one roller cone rotatably mounted on a cantilevered bearing shaft depending from said bit body; and, at least one cutter element extending from a primary row in said roller cone, said cutter element having a base portion adapted to fit into a corresponding socket on said roller cone and a non-rectilinear crest.

According to a second aspect of the present invention, there is provided a drill bit for cutting a formation, the bit comprising: a bit body having a bit axis; a plurality of rolling cone cutters rotatably mounted on cantilevered bearing shafts on said bit body, each rolling cone cutter having a generally conical surface; a first plurality of primary cutter elements extending from a first of said cone cutters in a first row, said first row extending to less than full gage; a second plurality of primary cutter elements extending from a second cone cutter in a second row, said second row extending to less than full gage, said second primary cutter elements intermeshing with said first primary cutter elements; and at least one of said primary cutter elements having a non-rectilinear crest and a base portion adapted to fit into a corresponding socket on a rolling cone cutter.

According to a third aspect of the present invention, there is provided a drill bit, the drill bit comprising: a bit body; at least two roller cones rotatably mounted on a cantilevered bearing shaft depending from said bit body; a first plurality of primary cutter elements extending from a first of said roller cones in a first row, said first row extending to less than full gage; a second plurality of primary cutter elements extending from a second roller cone in a second row, said second row extending to less than full gage, said second primary cutter elements intermeshing with said first primary cutter elements; and, at least one cutter element extending in a primary row from a roller cone, said cutter element having a base portion and an extending portion, said extending portion having a non-rectilinear crest and extending beyond the envelope defined by said base portion.

The bits of the present invention provide maximum scraping action and allow greater flexibility in the number of cutter elements used on a drill bit. At least one cutter element on a bit is provided with a non-rectilinear crest. The term "non-rectilinear" is used to refer to configurations that are other than straight lines and includes curvilinear crests. In a preferred embodiment, at least a portion of the non-rectilinear crest is curved so as to improve the distribution of forces through the cutter element. The concepts of the present invention can be used in cutter elements that have non-cylindrical and/or non-circular bases and can be used in tungsten carbide inserts and tungsten carbide inserts coated with superabrasives.

The cutter elements may have non-positive drafts. As used herein, the term "non-positive draft" refers to the cutting portion of the cutting element extending out to and beyond the envelope defined by the base portion.

Other objects and advantages of the present invention will become apparent upon reading the following detailed description and upon reference to the accompanying drawings in which:

Figure 1 is a perspective view of an earth-boring bit;

Figure 2 is a partial section view taken through one leg and one rolling cone cutter of the bit shown in Figure 1;

Figures 3A-D are top, front, side and perspective views, respectively, of a prior art chisel insert;

Figure 3E shows the cutter elements of a prior art drill bit rotated into a single plane;

Figures 4A-C are top, front, and side views, respectively, of a prior art conical insert;

Figures 5A-C are top, front and side views, respectively, of a chisel insert constructed in accordance with a first embodiment of the present invention;

Figures 6A-D are top, front, side and perspective views, respectively, of a chisel insert constructed in accordance with a second embodiment of the present invention;

Figure 6E shows the cutter elements of Figure 6A-D rotated into a single plane;

Figures 7A-C are top, front and side views, respectively, of an offset crest chisel with a negative draft;

Figure 8A-D are top, front and side views, respectively, of an offset crest chisel with a negative draft and a reinforcement rib;

Figure 9A-C are top, front and side views, respectively, of an offset conical insert with a negative draft;

Figure 10A-C are top, front and side views, respectively, of a biased negative draft chisel insert;

Figure 11A-C are top, front and side views, respectively, of a partial biased negative draft chisel insert;

Figure 12A-C are top, front and side views, respectively, of an arc crest chisel insert with zero draft;

Figure 13A-C are top, front and side views, respectively, of an arc crest chisel insert with negative draft;

Figure 14A-C are top, front and side views, respectively, of a spline crest chisel insert with zero draft;

Figure 15A-C are top, front and side views, respectively, of a spline crest chisel insert with negative draft;

Figure 16A-C are top, front and side views, respectively, of a partial negative draft chisel insert;

Figure 17A-C are top, front and side views, respectively, of an offset crest chisel insert with negative draft on its leading flank;

Figure 18A-C are top, front and side views, respectively, of a slant crest chisel insert with negative draft;

Figure 19 is a simplified illustration of a prior art insert pressing technique;

Figure 20 is a simplified illustration of an insert pressing technique in accordance with an embodiment of the present invention;

Figure 21 is a layout showing a first configuration of an example of cutter elements of the present invention with respect to a projection of the roller cone axis;

Figure 22 is a layout showing an alternative configuration of an example of cutter elements of the present invention with respect to a projection of the roller cone axis;

Figure 23 is a layout showing a second alternative configuration of an example of cutter elements of the present invention with respect to a projection of the roller cone axis;

Figure 23A is a different view of the configuration of Figure 23, looking along the axis of the cutter element and showing its orientation with respect to a projection of the cone axis;

Figure 24 is a layout showing a third alternative configuration of an example of cutter elements of the

present invention with respect to a projection of the roller cone axis;

Figures 25A-D are top, front, side and perspective views, respectively, of an arc crest chisel insert with positive draft;

Figures 26A-D are top, front, side and perspective views, respectively, of a spline or S-shape crest chisel insert with positive draft;

Figures 27A-D are top, front, side and perspective views, respectively, of a spline or S-shape crest chisel insert with positive draft in which the direction of the S is reversed as compared to the S shown in Figures 26A-D;

Figures 28A-D are top, front, side and perspective views, respectively, of a chisel insert having a J-shape crest and a positive draft;

Figures 29A-D are top, front, side and perspective views, respectively, of a chisel insert having a J-shape crest and a positive draft in which the direction of the "J" is reversed as compared to the "J" shown in Figures 28A-D;

Figures 30A-D are top, front, side and perspective views, respectively, of an insert having an arcuate crest that is not perpendicular to the longitudinal axis of the insert; and,

Figures 31A-D are top, front, side and perspective views, respectively, of an insert having an arcuate crest and a concave leading face.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and are described in detail below. It should be understood, however, that the drawings and detailed description thereof are not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the scope of the present invention as defined by the appended claims.

Referring first to Figure 1, an earth-boring bit 10 includes a central axis 11 and a bit body 12 having a threaded section 13 on its upper end for securing the bit to the drill string (not shown). Bit 10 has a predetermined gage diameter as defined by three rolling cone cutters 14, 15, 16, which are rotatably mounted on bearing shafts that depend from the bit body 12. Bit body 12 is composed of three sections or legs 19 (two shown in Figure 1) that are welded together to form bit body 12. Bit 10 further includes a plurality of nozzles 18 that are provided for directing drilling fluid toward the bottom of the borehole and around cutters 14-16. Bit 10 further includes lubricant reservoirs 17 that supply lubricant to the bearings of each of the cutters.

Referring now to Figure 2, in conjunction with Figure 1, each cutter 14-16 is rotatably mounted on a pin or journal 20, with an axis of rotation 22 orientated generally downwardly and inwardly toward the centre of the bit. Drilling fluid is pumped from the surface through fluid passage 24 where it is circulated through an internal passageway (not shown) to nozzles 18 (Figure 1). Each cutter 14-16 is typically secured on pin 20 by ball bearings 26. In the embodiment shown, radial and axial thrust are absorbed by roller bearings 28, 30, thrust washer 31 and

thrust plug 32; however, the invention is not limited to use in a roller bearing bit, but may equally be applied in a friction bearing bit. In such instances, the cones 14, 15, 16 would be mounted on pins 20 without roller bearings 28, 30. In both roller bearing and friction bearing bits, lubricant may be supplied from reservoir 17 to the bearings by apparatus that is omitted from the figures for clarity. The lubricant is sealed and drilling fluid excluded by means of an annular seal 34. The borehole created by bit 10 includes sidewall 5, corner portion 6 and bottom 7, best shown in Figure 2. Referring still to Figures 1 and 2, each cutter 14-16 includes a backface 40 and nose portion 42 spaced apart from backface 40. Cutters 14-16 further include a frustoconical surface 44 that is adapted to retain cutter elements that scrape or ream the sidewalls of the borehole as cutters 14-16 rotate about the borehole bottom. Frustoconical surface 44 will be referred to herein as the "heel" surface of cutters 14-16, it being understood, however, that the same surface may be sometimes referred to by others in the art as the "gage" surface of a rolling cone cutter.

Extending between heel surface 44 and nose 42 is a generally conical surface 46 adapted for supporting cutter elements that gouge or crush the borehole bottom 7 as the cone cutters rotate about the borehole. Conical surface 46 typically includes a plurality of generally frustoconical segments 48 generally referred to as "lands" which are employed to support and secure the cutter elements as described in more detail below. Grooves 49 are formed in cone surface 46 between adjacent lands 48. Frustoconical heel surface 44 and conical surface 46 converge in a circumferential edge or shoulder 50. Although referred to herein as an "edge" or "shoulder," it should be understood that shoulder 50 may be contoured, such as by a radius, to various degrees such that shoulder 50 will define a

contoured zone of convergence between frustoconical heel surface 44 and the conical surface 46.

In the bit shown in Figures 1 and 2, each cutter 14-16 includes a plurality of wear resistant inserts 60, 70, 80 that include generally cylindrical base portions that are secured by interference fit into mating sockets drilled into the lands of the cone cutter, and cutting portions connected to the base portions having cutting surfaces that extend from cone surfaces 44, 46 for cutting formation material. The present invention will be understood with reference to one such cutter 14, cones 15, 16 being similarly, although not necessarily identically, configured.

Cone cutter 14 includes a plurality of heel row inserts 60 that are secured in a circumferential row 60a in the frustoconical heel surface 44. Cutter 14 further includes a circumferential row 70a of nestled gage inserts 70 secured to cutter 14 in locations along or near the circumferential shoulder 50 to cut the borehole wall. Cutter 14 further includes a plurality of primary bottom-hole cutting inserts 80, 81, 82, 83 secured to cone surface 46 and arranged in spaced-apart inner rows 80a, 81a, 82a, 83a, respectively. Relieved areas or lands 78 (best shown in Figure 1) are formed about nestled gage cutter elements 70 to assist in mounting inserts 70. As understood by those skilled in this art, heel inserts 60 generally function to scrape or ream the borehole sidewall 5 to maintain the borehole at full gage and prevent erosion and abrasion of heel surface 44. Cutter elements 81, 82 and 83 of inner rows 81a, 82a, 83a are employed primarily to gouge and remove formation material from the borehole bottom 7. Inner rows 80a, 81a, 82a, 83a are arranged and spaced on cutter 14 so as not to interfere with the inner rows on each of the other cone cutters 15, 16.

It is common for some of the cutter elements to be arranged on conical surface 46 so as to "intermesh" with each other. More specifically, performance expectations require that the cone bodies be as large as possible within the borehole diameter so as to allow use of the maximum possible bearing size and to provide adequate recess depth for cutter elements. To achieve maximum cone cutter diameter and still have acceptable insert protrusion, some of the rows of cutter elements are arranged to pass between the rows of cutter elements on adjacent cones as the bit rotates. In some cases, certain rows of cutter elements extend so far that clearance areas corresponding to these rows are provided on adjacent cones so as to allow the primary cutter elements on adjacent cutters to intermesh farther. The term "intermesh" as used herein is defined to mean overlap of any part of at least one primary cutter element on one cone cutter with the envelope defined by the maximum extension of the cutter elements on an adjacent cutter.

Referring now to the particular construction of cutter elements, a prior art chisel insert 90 is shown in Figures 3A-D and a prior art conical insert 92 is shown in Figures 4A-C. As shown in these figures, the entire cutting portion of the insert is contained within the envelope of the cylindrical base portion. This is because the conventional way of manufacturing these inserts is by a punch and die method, which requires positive draft at the cutting portion so as to allow the die halves to separate after pressing operations. This restriction in manufacturing process imposes limitations on the geometry of the cutting portion of the insert. These limitations in turn prevent the optimisation of this geometry for maximising the bottom hole coverage and scraping action needed to increase rate of penetration in soft formations. Typical positive draft angles utilised in the manufacturing

of these inserts are not less than 10 degrees as measured per side, as shown in Figures 3B and 4B.

While the following discussion and corresponding Figures relate principally to cutter inserts having cylindrical bases with a circular or oval or elliptical cross-section, it will be understood that the principles of the present invention can be applied with equal advantage to cutter inserts having non-cylindrical and/or non-circular bases. The bases may be of any convenient cross-sectional shape. The bases may be cylindrical, for example tapered or frustoconical. In cutter elements having non-cylindrical or non-circular bases, positive draft refers to instances where the entire cutting portion of the insert is contained within the envelope defined by projecting the shape of the base portion along the longitudinal axis of the cutter element. As used herein, the phrase "longitudinal axis" refers to the longitudinal axis of the base portion.

Referring now to Figures 5A-C, a chisel insert 100 having an expanded geometry provides for increased mechanical scraping/shearing action by providing increased crest length beyond that formed on prior art inserts manufactured using conventional manufacturing techniques. Insert 100 includes base 102 and cutting portion 104. The insert axis is shown as "a". Further optimisation of mechanical scraping/shearing action can be achieved with additional expansion of cutting portion geometry as shown in Figures 6A-D. As shown in Figures 6A-D, insert 110 has a cylindrical base 112 of non-circular (e.g. oval or elliptical) cross-section and cutting portion 114 which includes expanded crest 116. Using the terminology employed with conventional manufacturing means, this insert has a negative draft 114 on the cutting portion which extends beyond the envelope "e" of the cylindrical base

portion. It is preferably made by the manufacturing techniques described below.

Conventional roller cone drill bits generate an uncut area on the bore hole bottom known in the art as uncut bottom as shown in Figure 3E. In Figure 3E, the cutter elements from all rolling cone cutters are depicted in rotated profile, that is, with the cutting profiles of the cutter elements shown as they would appear if rotated into a single plane. The uncut bottom is the area on the bore hole bottom that is not contacted by the crests of the primary row cutter elements. If this uncut area is allowed to build up, it forms a ridge. In some drilling applications, this ridge is never realised because the formation material is easily fractured and the ridge tends to break off. In very soft rock formations that are not easily fractured, however, the formation yields plastically and the ridge builds up. This ridge build-up is detrimental to the cutter elements and slows the drill bit's rate of penetration. Ridges of rock left untouched by conventional cutting structure arrangements are reduced or eliminated by the use of the present invention as illustrated in Figure 6E. Figure 6E shows the reduction in uncut bottom or increased bottom hole coverage provided by the expanded crest geometry of the cutter elements.

To obtain the same degree of bottom hole coverage shown in Figure 6E using conventional cutter elements, the diameter of the base portion of the cutter elements would typically be increased to achieve the corresponding increase in crest width. This increase in insert diameter would have the result of reduced clearance between inserts in the same row, as well as decreased insert-to-insert clearances between adjacent cones. To achieve adequate clearances in these areas would require severe compromise

in insert count and placement. These compromises are avoided through the use of the present invention.

The present invention is particularly suited for cutter elements used in the primary rows where, in soft formations, maximum shearing and scraping action of the rock is the preferred method of cutting. Cutter elements with elongate crests are used in these formations to provide shearing capability. The crest width of these cutter elements inserts influences the aggressiveness of the cutting action relative to the formation. Thus, the function of expanded crest widths on an insert can increase the volume of shearing/scraping performed by the cutter element relative to a conventional prior art chisel insert.

Hard formations can also be addressed by the present bit. Increased cutter volume can be attained by expanding the insert extension beyond the base while maintaining effective clearances between cutter elements in adjacent positions in the same row and between elements in adjacent rows (both on the same cone and in different cones). With an expanded insert extension and a reduced base diameter, insert quantities can be increased, thereby providing greater cutter density with additional strikes to the formation. The increase in cutter density also provides additional wear time for the insert, thereby extending bit life.

Depending on the shape and/or orientation of the cutter element, bottom hole coverage can be maximised to reduce or eliminate the amount of uncut hole bottom. If the cutter elements are positioned to maximise bottom hole coverage, the number of bit revolutions necessary to gouge and scrape the entire hole bottom can be reduced 40-60% from a typical conventional 3-cone tungsten carbide insert (TCI) rock bit.

Cutter Element Shapes

There are numerous variations within the scope of the present invention for the configuration of the cutting portion of the insert that extends beyond the envelope of the base portion. The geometry of the cutting element can be sculptured or non-sculptured. As used herein, the terms "contoured", "sculpted" and "sculptured" refer to cutting surfaces that can be described as continuously curved surfaces wherein relatively small radii (typically less than 0.08 inches (approximately 2mm)) are not used to break sharp edges or round-off transitions between adjacent distinct surfaces as is typical with many conventionally-designed cutter elements. The cutting portion of the cutting element can extend up to and beyond the envelope of its base anywhere along the perimeter of the base portion and any multitude of times. The preferred manufacturing techniques described below allow for new insert shapes that extend up to and beyond the "envelope" of the base portion of the insert thereby opening the door for countless new geometries. Several embodiments of the invention as applied to insert type cutter elements are illustrated in Figures 5 through 18. Like the embodiments shown in Figures 5A-C, 6A-D, these embodiments incorporate the principles of the present invention. In some embodiments, the longitudinal axis of the cutter element does not intersect the crest of the cutter element. For each embodiment shown in Figures 7 through 18, the comments in Table I set out the mechanical advantages that are believed to result from the specific features of that embodiment.

Table I

Figure Number	Insert Description	Comment
Figure 7A-C	Offset crest chisel with negative draft.	Optimise aggressive scraping action in specific applications.

Figure 8A-C	Offset crest chisel with negative draft and reinforcement rib.	The reinforcement rib provides increased support to improve durability when drilling through hard stringers.
Figure 9A-C	Offset conical with negative draft.	Optimise scraping action in non-plastic formations.
Figure 10A-C	Biased negative draft chisel.	Optimise scraping action where insert-to-insert clearances between cones is constrained.
Figure 11A-C	Partial biased negative draft chisel.	Optimise scraping action where insert to insert clearances between cones is constrained.
Figure 12A-C	Arc crest chisel with zero draft.	Structural support for insert crest/corners and improved scraping action.
Figure 13A-C	Arc crest chisel with negative draft.	Structural support for insert crest/corners and optimised scraping action.
Figure 14A-C	Spline crest chisel with zero draft.	Structural support for insert crest/corners and improved scraping action.
Figure 15A-C	Spline crest chisel with negative draft.	Structural support for insert crest/corners and optimised scraping action.
Figure 16A-C	Partial negative draft chisel.	Insert chisel crest corner protection for tougher applications.
Figure 17A-C	Offset crest chisel with negative draft on leading flank.	Aggressive positive rake for maximum formation removal.
Figure 18A-C	Slant crest chisel with negative draft.	Increased unit load upon entering the formation to

		maximise penetration.

Cutter Element Placement

Further optimisation of the cutter elements of the present invention can be achieved by their orientation and placement within the cone bodies. This will further maximise the desired level of scraping action for increased mechanical efficiency.

Referring to Figure 21, inserts 110 are shown placed in a conventional orientation in a row 110a with the axis of each insert being coplanar with the cone axis. Another arrangement is shown in Figure 22, in which each insert 110 is oriented in the cone body such that the axis "a" of the cylindrical portion of the insert is offset a distance "D" with respect to the cone axis. This further gives the designer flexibility to optimise the scraping action with regard to the specific formation and application.

Figures 23 and 23A show another orientation, wherein the crest 116 of the insert 110 is rotated about the insert axis "a" such that an angle α is defined with respect to the projection of the cone axis, as best seen in Figure 23A. It will be understood that in certain applications, it may be advantageous to rotate one or more inserts in the opposite direction such as by an amount α'. Figure 24 shows still another embodiment, wherein the insert 110 is both offset a distance "D" and rotated about its axis "a". Any of the inserts shown in Figures 5 - 18 and Figures 25-31 (discussed below) can be employed in the arrangements or orientations shown in Figures 21 - 24. The cutter elements 110 can be mechanically or metallurgically secured into the cone by various methods, such as interference fit, brazing,

welding, moulding, casting, or chemical bonding. The inserts shown in Figures 5, 7-18 and 21 - 24 are shown with a cylindrical base portion of circular cross-section for interference fit into a matching socket. The base portion of each insert need not be cylindrical nor of circular cross-section, however, as shown in Figures 6A-D.

Insert Material Types

An insert of the present invention can be made of tungsten carbide and in addition can be partially or fully coated with a "superabrasive" (i.e., a material having a hardness of at least 2,700 Knoop kg/mm^2) such as PCD, PCBN, etc.

Bit Design Intent

Depending on the bit design objectives, the amount of uncut bottom can be reduced or eliminated. Currently, most bits are designed with cutter intermesh between the rolling cones, which can invoke limitations on the wider crest of the cutter elements. Hence, designing bits without intermesh can allow greater latitude in crest width. The cutter elements of the present invention can be used in bits that have intermeshed cutter elements, as well as in those that do not.

Additionally, these cutter elements can be used in all types of rolling cone bits having one, two or more rolling cones.

The increased bottom hole coverage attainable with the present invention permits the use of fewer rows of cutter elements on the cone cutters of the bit. Having fewer rows of cutter elements, as compared to conventional prior art bits, increases the unit loading per cutter element thus

increasing the rate of penetration. For example, in one conventional 3-cone TCI roller cone bit, a total of nine rows of primary cutter elements dispersed among the three cones were employed to cut the bottom hole as shown in rotated profile in Figure 3E, there being three rows, specifically Rows 7, 8 and 9, aligned in the same rotated profile position. Using the expanded crest geometry described herein, and as shown in rotated profile Figure 6E, the bottom hole coverage can be attained using only a total of 8 rows of cutter elements on this 3-cone bit. Thus, TCI bits can be designed with 8 or fewer rows, in contrast to conventional prior art TCI bits, which typically have 9 or more rows.

Insert Manufacturing Techniques

Conventional rolling cone bit inserts are manufactured by press and die operations. As shown in Figure 19, the top and bottom dies 8, 3 are pressed axially, to form an insert 1 with a cylindrical base 9 and a cutting element extension 2, contained within the envelope of the cylindrical base. Positive draft must be designed into the extension within the constraints of the cylindrical base. Draft refers to the taper given to internal sides of a closed-die to facilitate its removal from the die cavity. To complete the conventional insert 1, a centreless grind operation is performed on the base portion 9 to provide specified cylindrical geometry and surface finish. In centreless grinding, the insert 1 is supported on a work rest and fed between the grinding wheel and a rubber bonded abrasive regulating wheel. Guides on either side of the wheels direct the work to and from the wheels in a straight line.

When inserts have extension geometries that extend out to and beyond the envelope of the cylindrical base,

conventional manufacturing techniques such as axial insert pressing and centreless grinding cannot be used. Techniques have been and are being developed to provide the ability to create the inserts such as those shown in Figures 5 - 18. For example, instead of pressing each insert along the longitudinal axis of its base "a", the inserts (such as insert 110) can be pressed normal to that axis, as shown in Figure 20, thus creating sides instead of a top and bottom. The present insert 110 can also be manufactured by injection moulding, multi-axis CNC milling machine, wire EDM, casting, stereolithography or other free-forming methods.

The insert base portion 112 can be finished by using other grinding methods (post grinder, in-feed centreless grinder) or by single point machining (turning).

Non-Rectilinear Crests

Figures 12, 13, 14 and 15 show examples of non-positive draft cutter elements having non-rectilinear crests. Specifically, the cutter elements shown in Figures 12, 13, 14 and 15, have non-rectilinear crests when viewed along their longitudinal axes. Non-rectilinear crests are defined as crests that are elongate and curvilinear in nature when viewed along the longitudinal axis "a" of the inserts, as shown in Figures 12A, 13A, 14A, and 15A. It is preferred that the non-rectilinear crest also be substantially uniform in width when viewed along longitudinal axis "a". However, crests having non-uniform widths are contemplated as being within the scope of the present invention.

It has been found that these non-rectilinear crests, sometimes referred to herein as "curvilinear crests", have distinct advantages in some formations. The advantages of

the curvilinear crests are realised in cutter elements having positive drafts, as well as in the non-positive draft cutter elements described above. Specifically, referring to Figures 25A-D through 31A-D, various preferred embodiments of cutter elements having curvilinear crests and positive drafts are shown.

Referring initially to Figure 25A-D, a cutter element 300 having an arcuate crest 302 and a positive draft is shown. The lines of the arcuate crest 302 are continued down the leading and trailing faces of cutter element 300, resulting in a concave leading face 304 and a convex trailing face 306. As shown, the left and right sides of cutter element 300 are symmetrical, but it will be understood that they could be asymmetrical and still achieve the desired features. Likewise, and as discussed above, the arcuate crest can be used in conjunction with cutter elements having zero or negative drafts as well.

Referring now to Figure 26, a cutter element 310 having an S-shape crest 312 and a positive draft has a leading face 314 that is both partially concave and partially convex and a trailing face 306 that is also partially concave and partially convex. Again, the sides of the cutter element are shown as being symmetrical, but could also be asymmetrical if desired. Also, the S-shape crest can be used in conjunction with cutter elements having zero or negative drafts.

In Figure 27, an alternative embodiment of the cutter element of Figure 26 is shown as 320, wherein the curves of the S-shape crest are reversed as compared to Figure 26. This results in a reversal of the convex and concave portions of the leading and trailing faces 324, 326 respectively. While this embodiment is shown having a

positive draft, it could be applied with equal advantage to cutter elements having zero or negative drafts as well.

Figure 28 shows a cutter element 330 having a J-shape crest 332, which results in the concave portion of the leading face and the convex portion of the trailing face being off-centre and closer to one side of the cutter element as drawn. Similarly, in Figure 29, a cutter element 340 has a J-shape crest, in which the convex and concave portions are offset in the opposite direction as compared to cutter element 330.

Figures 30A-D show a cutter element 350 having an arcuate crest 352 that is inclined with respect to the longitudinal axis of the insert. This inclination is not typically perceptible in the top view (Figure 30A), but can be seen in the front view (Figure 30B). While the other curvilinear crest shapes described above are shown with substantially straight or bowed shapes, it will be understood that any of the curvilinear crests can be canted with respect to the axis of the cutter element base. Similarly, Figures 31A-D show an insert 360 having an arcuate crest 362, a concave leading face 364, and a convex trailing face 366 when viewed along the longitudinal axis of the insert, as shown in Figure 31A. The concave/convex combination functions to increase the bending strength of the extending portion of the cutter element.

The various features described above, including curvilinear crests, inclined or bowed crests, concave and convex faces and variations in draft, can be combined and optimised to provide improved wear resistance and enhanced ROP, depending on the formation and other structure. Each of these concepts can also be applied with equal advantage to cutter elements having positive, zero or negative drafts. Both the durability and ROP potential of a

curvilinear crest insert can be substantially improved as compared to a similarly proportioned conventional insert designed with a straight or linear crest.

For example, as the roller cone rotates, the crest of each insert first engages the formation when the longitudinal axis of the insert is not perpendicular to the formation surface. This non-perpendicular loading condition induces bending or tensile stresses in the insert, which can cause chipping and/or breakage of the cutting element. These stresses are particularly pronounced at the "corners" of the crest (i.e. the opposing ends of the crest). By introducing a curvilinear crest (e.g. C-, S-, or J-shape), one or both of the corners of the insert are offset from the longitudinal axis toward the leading side. These offset corners of the insert initially engage the formation when the axis of the cutter element is closer to perpendicular. Hence, the reactive forces from the formation reduce tensile stress in the insert at initial engagement when impact forces/loads on the insert are at their maximum. This is advantageous, as tungsten carbide has a very high compressive strength and relatively lower tensile strength. Additionally, this improved "angle of initial penetration" provides a more aggressive and efficient cutting action that can improve ROP. Offsetting the crest corners also creates a convex trailing side surface, in planes both parallel and perpendicular to the longitudinal axis, which adds more carbide mass for support of reactive forces from the formation.

As the insert crest continues into the formation, the "C" shape crest for example improves the stress distribution within the insert. Any forces applied to the crest corner will have a force component vector directed along a tangent to the curvilinear centreline of the crest. This force component reduces the force component

perpendicular to the crest, which is against the weaker moment of the cross-sectional area in the local region, thereby reducing the tensile stress of bending.

In addition, the concavity in the leading side (in a plane perpendicular to the longitudinal axis) mechanically lifts the formation from the hole bottom, instead of forcing or ploughing the formation to the side(s). This allows drilling fluid to penetrate beneath the resultant "chip" and reduces the hold-down force applied by the drilling fluid column. For these reasons, the present curvilinear shapes are particularly advantageous in plastic formation types.

By way of another example, the spline, or S-crested cutter elements of Figures 14, 15, 26 and 27 have cutting leading and trailing faces that each include both concave and convex portions. This creates a twisting force as each cutter element penetrates and then translates through into the rock. This causes the rock to fail in tension rather than compression, increasing ROP.

While various preferred embodiments of the invention have been shown and described, modifications thereof can be made by one skilled in the art without departing from the scope of the present invention. The embodiments described herein are exemplary only, and are not limiting. Many variations and modifications of the invention and apparatus disclosed herein are possible and are within the scope of the present invention. Accordingly, the scope of protection is not limited by the description set out above, but is only limited by the claims that follow, that scope including all equivalents of the subject matter of the claims.

CLAIMS

1. A drill bit, the bit comprising:

a bit body;

at least one roller cone rotatably mounted on a cantilevered bearing shaft depending from said bit body; and,

at least one cutter element extending from a primary row in said roller cone, said cutter element having a base portion adapted to fit into a corresponding socket on said roller cone and a non-rectilinear crest.

2. A bit according to claim 1, wherein said crest is arcuate.

3. A bit according to claim 1, wherein said crest is a substantially S-shape spline.

4. A bit according to claim 1, wherein said crest is J-shape.

5. A bit according to any of claims 1 to 4, wherein said cutter element has a leading face that includes both concave and convex portions when viewed along the longitudinal axis of the cutter element.

6. A bit according to any of claims 1 to 4, wherein said cutter element has a concave leading face and a convex trailing face when viewed along the longitudinal axis of the cutter element.

7. A bit according to any of claims 1 to 6, wherein said base is non-circular in cross-section.

8. A bit according to any of claims 1 to 7, comprising at least two cutter elements have non-rectilinear crests.

9. A bit according to any of claims 1 to 8, wherein at least one cutter element has an extending portion having zero draft.

10. A bit according to any of claims 1 to 9, wherein at least one cutter element has an extending portion having negative draft.

11. A bit according to any of claims 1 to 10, wherein at least one cutter element has an extending portion having positive draft.

12. A bit according to any of claims 1 to 11, wherein at least one cutter element has an extending portion having a contoured surface.

13. A bit according to any of claims 1 to 12, wherein said at least one cutter element has a longitudinal axis and said longitudinal axis is offset such that it does not intersect the axis of said cone.

14. A bit according to any of claims 1 to 13, wherein said at least one cutter element has a longitudinal axis and said longitudinal axis does not intersect said crest.

15. A drill bit for cutting a formation, the bit comprising:

a bit body having a bit axis;

a plurality of rolling cone cutters rotatably mounted on cantilevered bearing shafts on said bit body, each rolling cone cutter having a generally conical surface;

a first plurality of primary cutter elements extending from a first of said cone cutters in a first row, said first row extending to less than full gage;

a second plurality of primary cutter elements extending from a second cone cutter in a second row, said second row extending to less than full gage, said second primary cutter elements intermeshing with said first primary cutter elements; and,

at least one of said primary cutter elements having a non-rectilinear crest and a base portion adapted to fit into a corresponding socket on a rolling cone cutter.

16. A bit according to claim 15, wherein said crest is arcuate.

17. A bit according to claim 15, wherein said crest is a substantially S-shape spline.

18. A bit according to claim 15, wherein said crest is J-shape.

19. A bit according to any of claims 15 to 18, wherein said cutter element has a leading face that includes both concave and convex portions when viewed along the longitudinal axis of the cutter element.

20. A bit according to any of claims 15 to 18, wherein said cutter element has a concave leading face and a convex trailing face when viewed along the longitudinal axis of the cutter element.

21. A bit according to any of claims 15 to 20, wherein said cutter element has a longitudinal axis and said longitudinal axis is offset such that it does not intersect the axis of said cone.

22. A bit according to any of claims 15 to 21, wherein said base is non-circular in cross-section.

23. A bit according to any of claims 15 to 22, wherein at least two cutter elements have non-rectilinear crests.

24. A bit according to any of claims 15 to 23, wherein at least one cutter element has an extending portion having zero draft.

25. A bit according to any of claims 15 to 24, wherein at least one cutter element has an extending portion having negative draft.

26. A bit according to any of claims 15 to 25, wherein at least one cutter element has an extending portion having positive draft.

27. A bit according to any of claims 15 to 26, wherein at least one cutter element has an extending portion having a contoured surface.

28. A bit according to any of claims 15 to 27, wherein said cutter element has a longitudinal axis and said longitudinal axis does not intersect said crest.

29. A drill bit, the drill bit comprising:

a bit body;

at least two roller cones rotatably mounted on a cantilevered bearing shaft depending from said bit body;

a first plurality of primary cutter elements extending from a first of said roller cones in a first row, said first row extending to less than full gage;

a second plurality of primary cutter elements extending from a second roller cone in a second row, said second row extending to less than full gage, said second primary cutter elements intermeshing with said first primary cutter elements; and,

at least one cutter element extending in a primary row from a roller cone, said cutter element having a base portion and an extending portion, said extending portion having a non-rectilinear crest and extending beyond the envelope defined by said base portion.

30. A bit according to claim 29, wherein said crest is arcuate.

31. A bit according to claim 29, wherein said crest is a substantially S-shape spline.

32. A bit according to claim 29, wherein said crest is J-shape.

33. A bit according to any of claims 29 to 32, wherein said cutter element has a leading face that includes both concave and convex portions when viewed along the longitudinal axis of the cutter element.

34. A bit according to any of claims 29 to 32, wherein said cutter element has a concave leading face and a convex trailing face when viewed along the longitudinal axis of the cutter element.

35. A bit according to any of claims 29 to 34, wherein said base is non-circular in cross-section.

36. A bit according to any of claims 29 to 35, wherein at least two cutter elements have non-rectilinear crests.

37. A bit according to any of claims 29 to 36, wherein said extending portion has a contoured surface.

38. A bit according to any of claims 29 to 37, wherein said cutter element has a longitudinal axis and said longitudinal

axis is offset such that it does not intersect the axis of said cone.

39. A bit according to any of claims 29 to 38, wherein said cutter element has a longitudinal axis and said longitudinal axis does not intersect said crest.

40. A drill bit substantially in accordance with any of the examples as hereinbefore described with reference to and as illustrated by the accompanying drawings.

41. A method of manufacturing a drill bit substantially in accordance with any of the examples as hereinbefore described with reference to and as illustrated by the accompanying drawings.

The Patent

34

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Claims searched: 1-41

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): E1F (FFD,FGA,FGC)

Int Cl (Ed.6): E21B

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US 5172779 (Smith International, Inc)	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.